Energy, Matter & Change

Laboratory Book

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Energy, Matter, and Change

Laboratory Book

Ronald D. Townsend
Paul DeHart Hurd
Senior Consultant

Teacher's Edition

Scott, Foresman and Company

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Table of Contents

To the Student **VIII**

UNIT 1: Light 1

CHAPTER 1: Why Color? 1
PROBLEM A: Is white light "colorless"? **1**
PROBLEM B: What happens to white light when it passes through transparent colored squares? **3**
YOUR TURN: How do other transparent colored objects affect the spectrum? **6**
PROBLEM C: What happens when a white-light spectrum strikes a colored surface? **7**
PROBLEM D: What happens when colored light strikes a colored surface? **9**
PROBLEM E: What happens when different colors are blended? **13**

CHAPTER 2: Mirror Reflections 19
PROBLEM A: What happens when light beams are reflected off the surface of a flat mirror? **19**
PROBLEM B: What kind of image is made by a flat mirror? **23**
YOUR TURN: Is an image reflected in the same way as a light beam? **25**
PROBLEM C: How are light beams reflected off the surface of concave mirrors? **27**
PROBLEM D: What kinds of images are made by concave mirrors? **31**

CHAPTER 3: Images Through a Pinhole 35
PROBLEM A: How do you make different kinds of pinhole images? **36**
YOUR TURN: What happens to the size of a pinhole image if the size of the pinhole is changed? **38**

CHAPTER 4: Lenses 39
PROBLEM A: What happens to a beam of light as it moves from air into another substance? **39**
PROBLEM B: What happens to light as it passes through a double-convex lens? **45**
PROBLEM C: How are double-convex lenses used in cameras and as magnifiers? **49**

UNIT 2: Electricity 51

CHAPTER 6: Measuring Electricity 51
PROBLEM A: What is an electrical circuit? **51**
PROBLEM B: What determines the amount of electricity which moves through a circuit? **55**
PROBLEM C: Why are some lights bright and others dim? **61**
YOUR TURN: How much is a watt? **64**

There are no lab activities that correspond to the text materials in Chapter 5: "The Brightness of Light."

PROBLEM D: How much electrical resistance is there in a circuit? **65**
YOUR TURN: What is the resistance of a flashlight bulb with two batteries in the circuit? **67**
PROBLEM E: When are two electrical paths better than one? **69**
PROBLEM F: When do two batteries make a bulb brighter? **73**

CHAPTER 7: Electricity and Magnetism 75
PROBLEM A: How do magnets behave? **75**
YOUR TURN: Can a magnet have three poles? **78**
PROBLEM B: What is a magnetic field? **79**
YOUR TURN: Do all magnetic fields have the same strength? **80**
PROBLEM C: What does an electric current have in common with a magnet? **81**
PROBLEM D: When is a coiled wire a magnet? **85**
PROBLEM E: What are some things that affect the strength of an electromagnet? **87**
PROBLEM F: How can a magnet produce an electric current? **91**

CHAPTER 8: The Whirring of Motors 93
PROBLEM A: How does an electric motor work? **93**
PROBLEM B: What affects the energy per second used by a motor? **97**
PROBLEM C: How can you generate electricity? **99**
YOUR TURN: How could you increase the electrical output of a generator? **102**

UNIT 3: Motion 103

CHAPTER 9: Things in Motion 103
PROBLEM A: How do you find the speed of an object? **103**
PROBLEM B: Why are some marbles harder to stop than others when they are all moving at the same speed? **107**
PROBLEM C: How do speed and mass of a moving object affect its motion? **113**
PROBLEM D: What happens to the momentum in a collision? **117**
YOUR TURN: Can you make the momentum of the "lightest" marble equal to the momentum of the "heaviest" marble? **120**

CHAPTER 10: Using Force 121
PROBLEM A: What happens when you apply constant force to a motion cart? **121**
YOUR TURN: Is the weight of the loaded motion cart the same as the force needed to pull it across 3 meters? **126**
PROBLEM B: What happens when you apply a constant force to a motion cart without wheels? **127**

PROBLEM C: What is happening when you apply force without changing the motion of an object? **129**

PROBLEM D: What happens when you apply forces at an angle? **133**

YOUR TURN: How do forces at an angle work when the forces are not equal? **136**

CHAPTER 11: Doing Work 137

PROBLEM A: What do you "save" when you use a pulley? **137**

YOUR TURN: Is there any advantage to using only one pulley? **142**

PROBLEM B: What do a seesaw and a ramp have in common with a pulley? **143**

YOUR TURN: How much work do you do going up steps? **148**

PROBLEM C: How does friction affect work input? **149**

CHAPTER 12: What Goes Up, Must Come Down 153

PROBLEM A: Can magnets exert a force? **153**

PROBLEM B: What do you get in return for work (besides money)? **157**

UNIT 4: Heat 161

CHAPTER 13: Temperature 161

PROBLEM A: Is your body surface an accurate thermometer? **161**

PROBLEM B: How can liquids and gases be used to measure temperature change? **163**

PROBLEM C: How do you make a scale for measuring temperature? **167**

PROBLEM D: How do some different substances respond to temperature change? **171**

YOUR TURN: How can you tell temperature differences on the surface of an object? **172**

CHAPTER 14: Supplying Heat 173

PROBLEM A: How are the temperatures of different masses of water affected when they receive the same amount of heat? **173**

PROBLEM B: How much heat can hot water supply to cool water? **177**

PROBLEM C: Do all metals supply the same amount of heat? **181**

YOUR TURN: Does steel, brass, or aluminum supply the most heat? **184**

CHAPTER 15: Boiling Water and Melting Ice 185

PROBLEM A: What happens when you supply heat to melting ice? **185**

PROBLEM B: What happens when you supply heat to boiling water? **189**

YOUR TURN: Can you change the boiling point of water? **192**

PROBLEM C: How does temperature affect the movement of liquids? **193**

UNIT 5: Chemistry 195

CHAPTER 16: Variety Is the Spice of Life 195
PROBLEM A: What are some methods you could use to tell whether substances are alike or different? 195
PROBLEM B: How can you separate substances in a mixture? 203

CHAPTER 17: Changing Substances 207
PROBLEM A: What happens in chemical changes? 207
PROBLEM B: Is there an energy change in chemical reactions? 217
PROBLEM C: What are some things that affect the speed of a chemical reaction? 223

CHAPTER 18: Metals 229
PROBLEM A: How can you arrange a group of metals according to the way they react with each other? 229
PROBLEM B: What are some ways to prevent rusting? 233

APPENDIX A: Renewing Your Skills 237
ACTIVITY A: Measuring length 237
ACTIVITY B: Using decimals 241
ACTIVITY C: Measuring angles with a protractor 245
ACTIVITY D: Using graphs 247
ACTIVITY E: Measuring mass with an equal-arm balance 253
ACTIVITY F: Measuring liquid volume with a graduate cylinder 255
ACTIVITY G: Finding the density of a solid and of a liquid 257

APPENDIX B: Additional Notes 259

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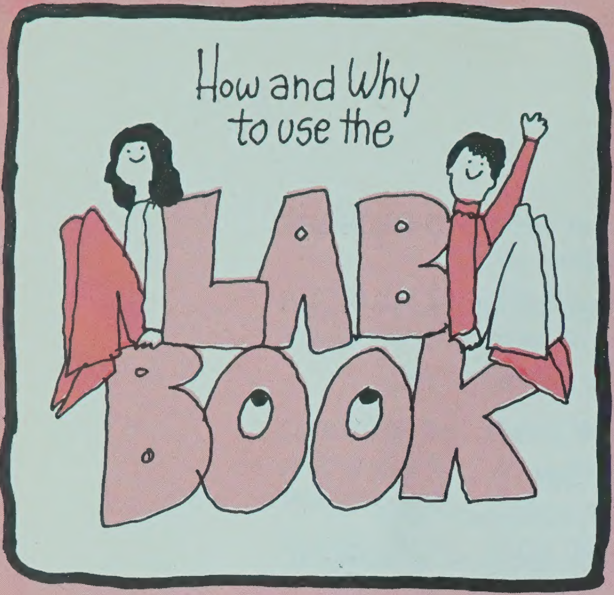


1. Follow the titles in the frames. Each title is a section of your Lab Book.

2. Try the activities in this section first. Have some fun. Learn to use new equipment. Then think about the questions that follow.

3. Investigate a science PROBLEM. Begin your investigation by following the instructions in this section.

4. Measure and record what you observe in the lab. Use the tables and graphs on these pages to help you.

5. Try to solve each lab problem by answering the questions asked here. (Sometimes you may be Tying ideas together from several problems or parts of a problem.)

6. If you have extra time . . . use the information here to investigate a problem on your own.

Some Things you should be able to DO NOW

7. Find out how much you have learned. Can you do everything listed in this section?

8. If you've forgotten a skill that you need in the lab . . . try these activities.

9. To avoid injuring yourself or the equipment, carefully follow the instructions next to this sign.

10. Extend your thinking! After doing the lab work, go to your text and read the pages suggested.

11. Develop skills in the lab you can use other places. What lab skills do these people use?

UNIT I: LIGHT

Name ______________________

Date __________ Class __________

CHAPTER 1: WHY COLOR?

BEFORE YOU BEGIN PROBLEM A . . .

Read "Light" and "Why Color?" pages 2–6 in your text.

Then take red, green, and blue squares of transparent plastic. Put the blue square on the green square. Look through both of them at a piece of white paper. What color do you see? Look through the blue and red squares. Then look through the red and green squares. What color do you see each time?

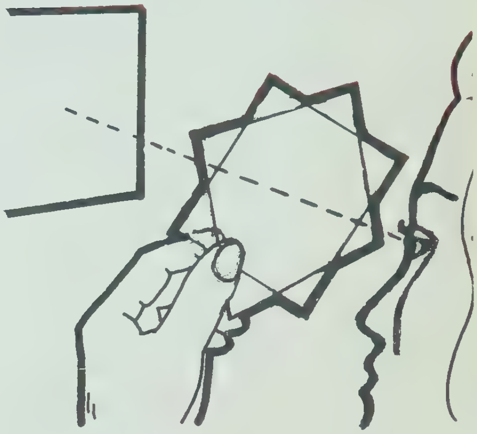
Take the cyan (blue-green), magenta (blue-red), and yellow plastic squares. Look through pairs of colored squares as you did above. What do you see this time? Now think about these questions:

—Is light made up of more than one color?

—What happens to light when it passes through a transparent colored object?

Since the room must be darkened for most of the activities in this unit, it might be helpful to schedule a room that will be dark for certain periods during the day. Students can use this room to work on the activities, while other students are using the regular classroom to read text materials or to work on activities that do not require a darkened room.

Have students use the transparent colored squares listed in the "Materials" section of Problem B.



PROBLEM A: *Is white light "colorless"?*

Materials: 1 Projector
1 White index card
1 Transmission diffraction grating
1 Paper slide with slit 3-mm wide
(Turn to page 263 for cutout A. Glue heavy black paper to back of page 263.)

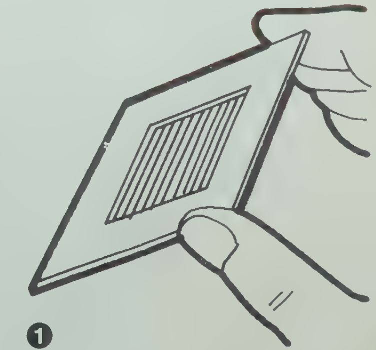
Investigating . . .

Look closely at the piece of plastic in the cardboard frame. Notice all the tiny lines scratched into its surface. The plastic is called a *diffraction grating*. ❶ You will learn more about the grating as you do the experiment.

1. Now cut out the paper slide marked *A* on page 263. Put this slide into your projector. Focus the projector beam on a nearby surface.

2. Hold the diffraction grating about 15 cm away from the projector. Make sure the lines on the grating are parallel to (run the same way as) the slit of light.

A projector is the best light source for the activities in this chapter. However any other strong light source you have available can be used, as long as you can get a parallel beam of light.
A prism can be used for this activity, but a diffraction grating produces the brightest and most distinct spectrum.
"Transmission" diffraction grating is the term by which this piece of equipment must be ordered.
Some of the cutouts are used for later activities. Have students make pockets for the backs of their books and store cutouts there.



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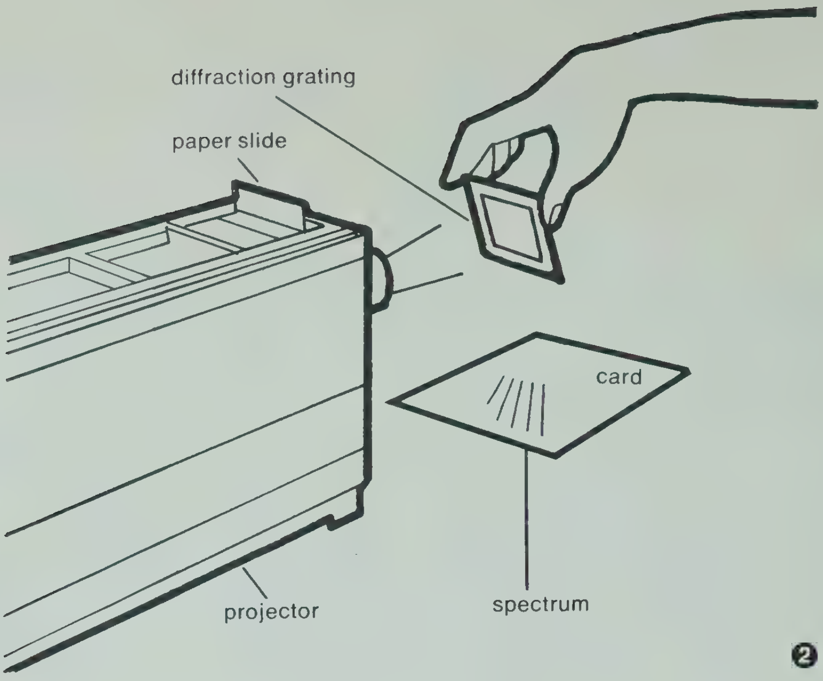


3. Tip the grating downward until you see a band of colors on the table. The band of colors is called a *spectrum*. To make the colors look brighter, put a white card under the spectrum. ❷ Record your observations.

Observing . . .

A. What colors do you see in the spectrum?

Red, orange, yellow, green, blue, indigo, violet. (Students may not see all these colors or may not be able to name them all.)

B. Which three colors look brightest?

Red, green, blue (or blue-violet).

Interpreting . . .

1. Now do you think white light is "colorless"? What observations did you make that support your answer?

   No. When white light strikes a diffraction grating, it is separated into many colors.

2. What do you think a diffraction grating does to light?

   It separates white light into bands of color (a spectrum).

3. A rainbow is a spectrum of sunlight. Name some things you think might break up sunlight into its colors.

   Possible answers: glass, water, raindrops.

Name ______________________

Date __________ Class __________

PROBLEM B: ***What happens to white light when it passes through transparent colored squares?***

To produce results that are meaningful to the students and that approximate the answers provided, you might want to test your filters by doing Problem B before class begins.

More accurate results are obtained by using a blue-violet filter, rather than a blue filter.

Materials: (See Problem A)

6 Transparent squares of colored plastic

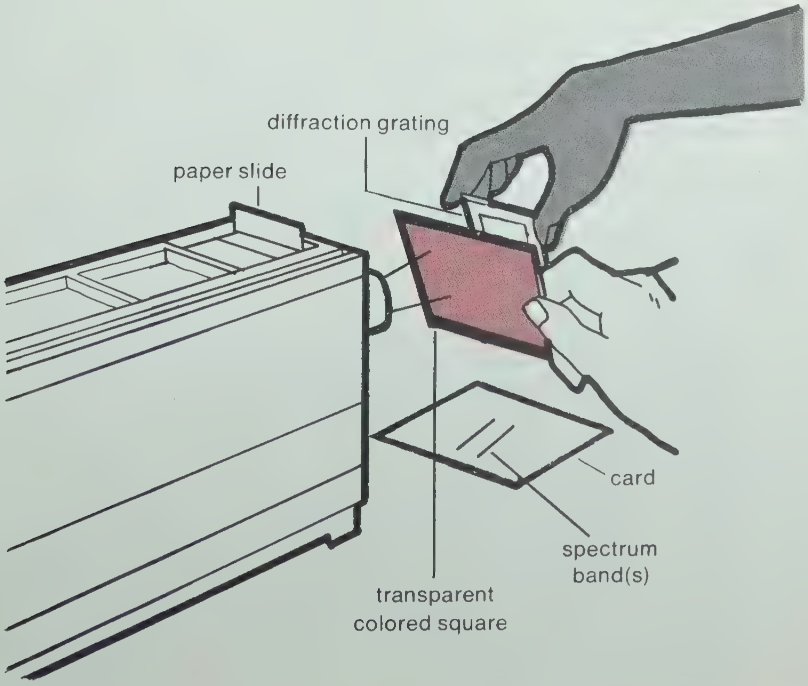
red	blue	cyan (blue-green)
green	yellow	magenta (red-blue)

I Investigating . . .

Make a spectrum the same way as you did in Problem A.

1. Place a transparent red square between your diffraction grating and the spectrum.
2. Look at the spectrum. Notice which of the three color bands—red, green, or blue—passes through the red square. Also note which of the color bands are blocked. Write down your observations in Table 1·1.

Repeat this activity with each of the other colored squares listed in Table 1·1. Write down *all* the color bands that pass through each colored square.



No filter is completely "pure" and individual perception of colors varies. For these reasons, the answers given represent the *ideal*. Allow for variations in student answers.

Observing . . .

Table 1·1

Color of square	Major color band(s) passed	Major color band(s) blocked
Red	Red	Green, Blue
Green	Green	Red, Blue
Blue	Blue	Red, Green
Yellow	Red, Green	Blue
Cyan (blue-green)	Blue, Green	Red
Magenta (red-blue)	Blue, Red	Green

Interpreting . . .

What happens to the color bands of the spectrum when light passes through a transparent colored square?

Some of the color bands are blocked by the square, and others pass through.

II **Investigating . . .**

Find out what happens to a spectrum when you hold two transparent squares of different colors in front of a light beam.

1. Predict which color band(s) will pass through the red and green squares. Write down your prediction in Table 1·2. Use your observations from Table 1·1 to help you out.

2. Hold both the red and the green squares together in front of the light from your projector. Notice the color you see on a white surface. Write down your observation in Table 1·2. Compare your prediction and your observation.

Name ____________________

Date __________ Class __________

3. Predict which color band(s) will pass through each of the other pairs of colored squares listed in Tables 1·2 and 1·3. Then make your observations.

Use a diffraction grating and a spectrum to check your observations. (See the directions under "Investigating . . . ," page 1.)

Allow for variation in student observations.

Observing . . .

A. Table 1·2

Color of squares	Colors seen	
	prediction	observation
Red and green	Variable	None, no color bands passed
Red and blue		
Blue and green		

B. Table 1·3

Color of squares	Colors seen	
	prediction	observation
Yellow and cyan	Variable	Green
Yellow and magenta		Red
Cyan and magenta		Blue

Interpreting . . .

1. What happens to the colors in the white-light spectrum when it passes through each pair of colored squares listed in Table 1·2?

   All the color bands in the spectrum are blocked by each pair of overlapped colored squares. You see no color, or black.

2. What happens to the colors in the white-light spectrum when it passes through each pair of colored squares listed in Table 1·3?

   One color band in the spectrum passes through each pair of overlapped colored squares, the rest are blocked. In each case, you see one spectrum color.

Tying ideas together:

Do transparent colored materials add color to or subtract color from light passing through them? Use your observations to support your answer.

Transparent colored squares subtract color from light passing through them. If transparent colored squares are held between white light and a spectrum, one or more of the spectrum colors do not pass through the square(s).

YOUR TURN: ***How do other transparent colored objects affect the spectrum?***

Make a spectrum. Hold a tinted sunglass lens (*not* Polaroid) between your diffraction grating and the spectrum. What happens? Explain your observations.

Find some other transparent colored objects. Hold them between your diffraction grating and the spectrum. Which colors are absorbed by each object? Which colors pass through?

Varying amounts of several spectrum colors pass through most transparent colored objects. For example, a red candy wrapper may pass bands of orange and yellow, as well as red. But the eye only "sees" the color red.

Before you continue, read "Does 'colorless' light contain color?" pages 7–10 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Use a diffraction grating to break white light into a spectrum.

2. Describe what happens to white light when it passes through transparent squares of certain colors.

3. Predict what will happen to the spectrum bands if transparent squares of certain colors are overlapped.

Name ______________________

Date __________ Class __________

PROBLEM C: ***What happens when a white-light spectrum strikes a colored surface?***

Materials: 7 Colored chalks

red blue cyan black
green yellow magenta

1 Projector
7 White index cards
1 Transmission diffraction grating
1 Paper slide with slit 3-mm wide
(See Problem A, p. 1)

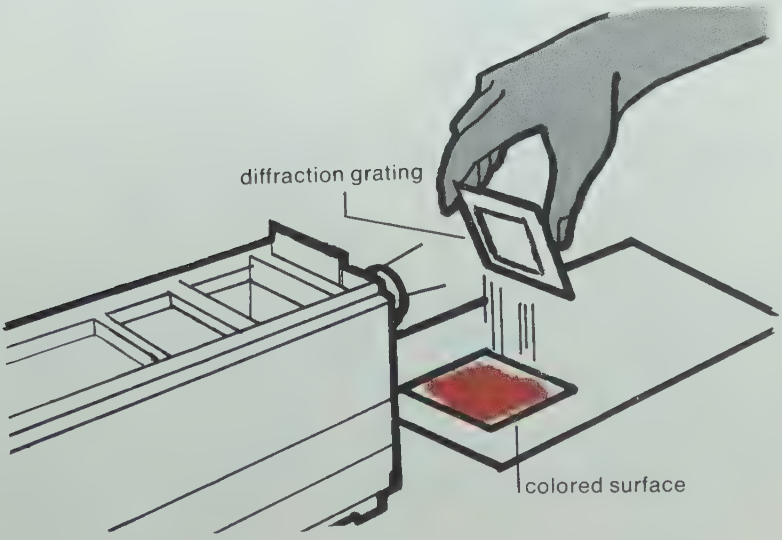
Investigating . . .

1. Pick out chalk to match the colors in Table 1·4. Use a different chalk color listed in the table to color each of the seven cards. Cover each card heavily with chalk. No white patches should show. ❶

2. Put your paper slide with a slit into the projector. Focus the light beam on a nearby surface.

3. Then hold a diffraction grating in the light beam. Tip the grating downward until you see a spectrum on the table. Move the grating around until the spectrum looks brightest.

4. Put the red card where you see the spectrum. ❷ In Table 1·4 put a number one (1) under the spectrum color that seems brightest on the red card. Put a



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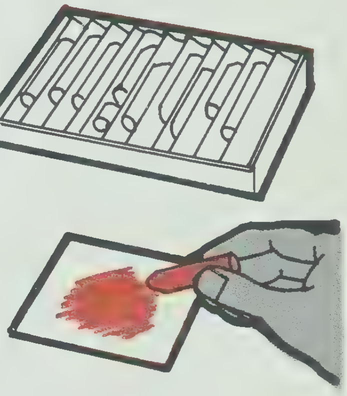
Be certain to use colored chalks for this activity, *not* colored paper. The surface of colored paper is too rough and the pigment too impure for students to get results that are meaningful. Similarly, water colors will not work well either.

You may wish to prepare the chalk surfaces yourself before class.

Pretest chalks before using them, so you can find the colors that work best. (Colored blackboard chalk works nicely.)



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The most accurate results are obtained using the following chalk colors:

Color needed for activity	Chalk color "that works"
Red	= Red
Green	= Dark Green
Blue	= Blue-Violet or Purple
Magenta	= Medium Purple
Cyan	= Blue-Green
Yellow	= Yellow

number two (2) under any other spectrum colors that you see, but that are less bright. The colors that you see are *reflected* off the red surface.

Record the spectrum colors you see reflected off the other colored surfaces listed in Table 1·4.

Observing . . .

Pigments are impure and vary in color. For this reason, the answers provided represent the *ideal*.

Table 1·4

Color of surface	Major spectrum colors reflected		
	red	green	blue
Red	1	2	2
Green	2	1	2
Blue	2	2	1
Yellow	1	1	2
Cyan	2	1	1
Magenta	1	2	1
Black	2	2	2

Interpreting . . .

1. Try to state a rule that describes what happens to a spectrum of white light when it strikes a colored surface.

   When a spectrum of white light strikes a colored surface, some of the spectrum colors are reflected back to your eyes more strongly than others.

Ask students to predict how a colored picture would look under colored light. Have them test their predictions.

2. Which color bands of the spectrum do you think would be reflected by (a) a white car, (b) a green leaf, (c) a yellow house?

   (a) All spectrum colors, (b) mostly the green band, (c) mostly the red and green bands.

Name ____________________

Date ________ Class ________

PROBLEM D: ***What happens when colored light strikes a colored surface?***

Materials: 6 Transparent squares of colored plastic

red blue cyan
green yellow magenta

7 Colored index cards from Problem A

red blue cyan black
green yellow magenta

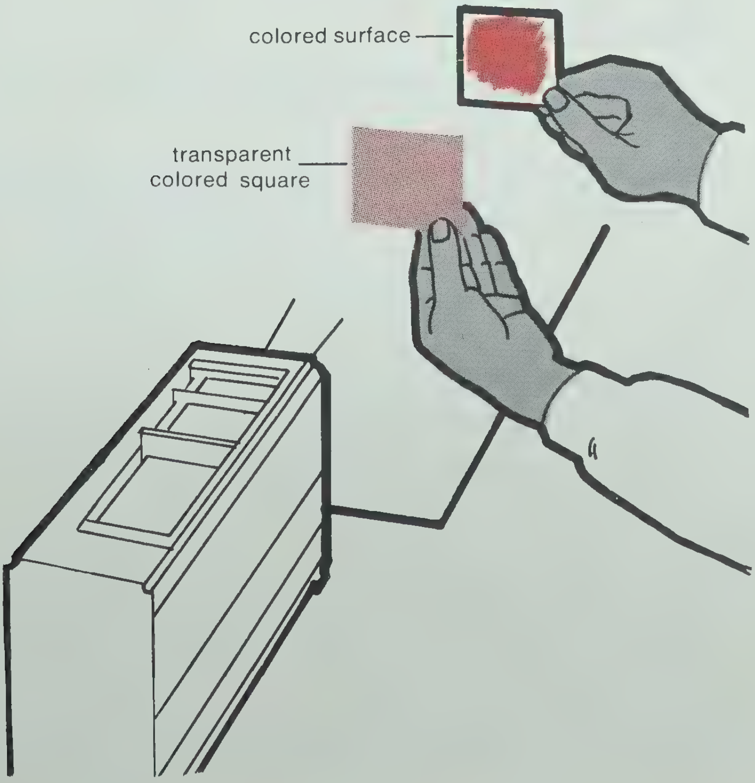
1 Projector

Investigating . . .

1. Place a red transparent square in front of a light beam. Shine the red light onto each colored surface you made in Problem C.

2. Observe the color of each surface under red light. In Table 1·5, record the colors you see.

Shine the other colored light beams listed in Table 1·5 on each of the other colored surfaces. Record what you see.



The observations for this activity will vary greatly due to (a) individual variation in color perception, (b) individual variation in color naming, or (c) variation in type of filters and colored surfaces used.

Observing . . .

Table 1·5: Appearance of colored surfaces under colored light

Color of light	Red surface	Green surface	Blue surface	Magenta surface	Cyan surface	Yellow surface	Black surface
Red	Variable						
Green							
Blue							
Magenta							
Cyan							
Yellow							

Interpreting . . .

1. When did any colored surfaces listed in Table 1·5 (a) stay the same color?

When the surface was the same color (under white light) as the filtered light from the projector.

(b) appear gray or black?

When the surface reflected none of the spectrum colors in the filtered light from the projector.

(c) seem to change color?

When the colored surface reflected some of the spectrum colors in the filtered light from the projector.

Name ____________________

Date __________ Class __________

2. What color will a green lime appear to be under a red neon sign? Give evidence to support your answer.

   Black. Light from a red neon sign contains the red spectrum band, but not the green spectrum band. So, green light cannot be reflected off the surface of the green lime. The lime will appear to be black.

3. Why do you think colored objects appear to be gray or black in dim light?

   Because the light is dim, very little light of any spectrum color is available to be reflected off colored surfaces.

4. If you wanted to go bike riding at night, would it be safest to wear red, yellow, or white? Why?

   White. White reflects all spectrum colors and would therefore reflect whatever light was available.

Before you continue, read "In green light will a 'red' object be red?" pages 12–13 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Perform an experiment to demonstrate what happens to the bands of the spectrum when the spectrum is reflected off a colored surface.

2. Describe the appearance of the spectrum when it is reflected off a colored surface.

3. Perform an experiment to demonstrate what happens when colored light strikes a colored surface.

4. Describe the effect of colored light on the appearance of a colored surface.

Name ______________________

Date ____________ Class ____________

BEFORE YOU BEGIN PROBLEM E . . .

Take a hand lens and use it to look at the color photos in your text on page 18. Describe how the solid colors appear when they are magnified. Look at the girl's green sweater in the top left photo. Is the green sweater really "green"? Now think about these questions:

—What happens when two different colors are mixed together?

—How does mixing colored paints differ from blending colored lights?

PROBLEM E: ***What happens when different colors are blended?***

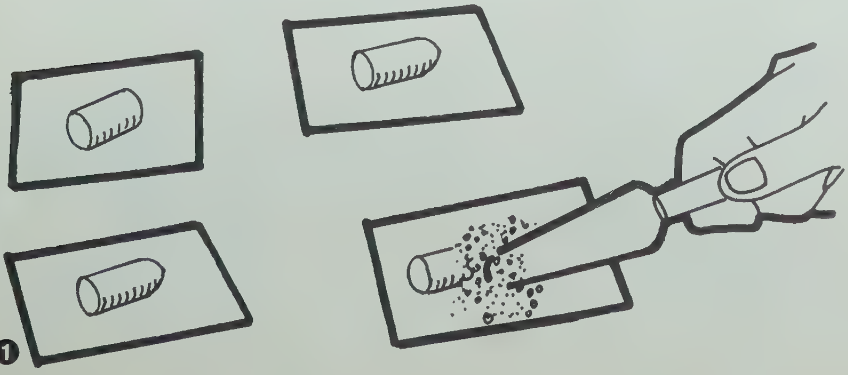
Materials: 3 Colored chalks
cyan yellow
magenta
6 Transparent squares of colored plastic
red blue yellow
green cyan magenta
16 White index cards
1 Metal spatula
8 Toothpicks (or wooden splints)
1 Hand lens
3 Projectors

I Investigating . . .

Find out what happens when colored *chalks* are mixed together.

Prepare the chalk before class.

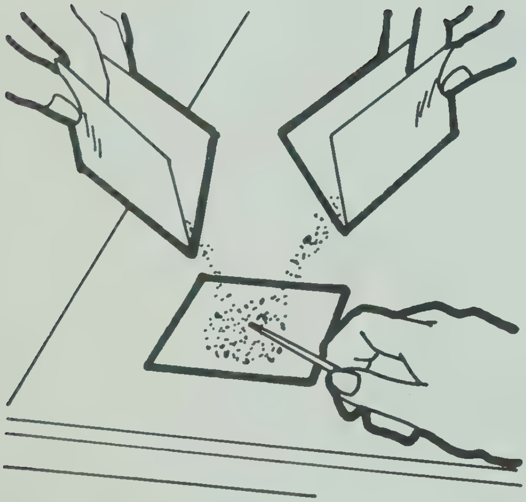
1. Pick out a magenta, a yellow, and a cyan chalk. Break each piece of chalk into four equal pieces. Use a spatula or some other flat metal surface to crush the pieces. CRUSH EACH CHALK PIECE ON A SEPARATE CARD. ①



①

2. Use a toothpick or wooden splint to mix the same amounts of magenta and yellow chalk. ❷ In Table 1·6, describe the color you see after the chalks are mixed.

3. Look at the mixture with your hand lens. ❸ Write down what you see in the space provided. If you have trouble deciding on the color of a chalk mixture, rub some into the card. If you do this, the color may look brighter.



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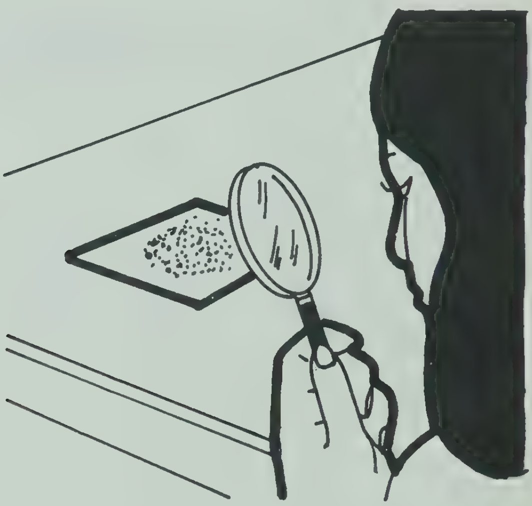


❸

Repeat the steps with each pair of colored chalks listed in Table 1·6. Write down your observations.

Observing . . .

Allow for some variation in student answers.

The chalk colors vary in purity, so some of the colors may appear to be "muddy."

A. Table 1·6

Chalk colors	Color of mixture
Magenta + Yellow	Red (Pink-Orange)
Magenta + Cyan	Blue (Blue-Violet)
Yellow + Cyan	Green
Magenta + Yellow + Cyan	Gray

Name ____________________

Date __________ Class __________

B. What do the chalk mixtures look like under a hand lens?

The mixtures are made up of different-colored particles.

Interpreting . . .

Why do you think you see the colors you do when chalks of two or more different colors are mixed together?

The colors are combined by your eyes, and you "see" a new or different color.

II Investigating . . .

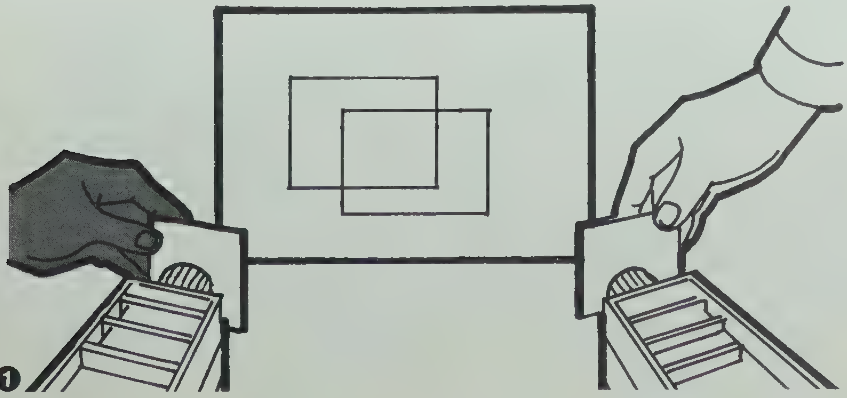
Find out what happens when colored *lights* are blended. You can do this activity with another group of students.

This part of the activity can be used as a teacher demonstration.

1. Predict the color you will see if red and green light beams are blended. (Use your observations in Table 1·1, page 4, to help you.) Record your prediction in the space provided in Table 1·7.

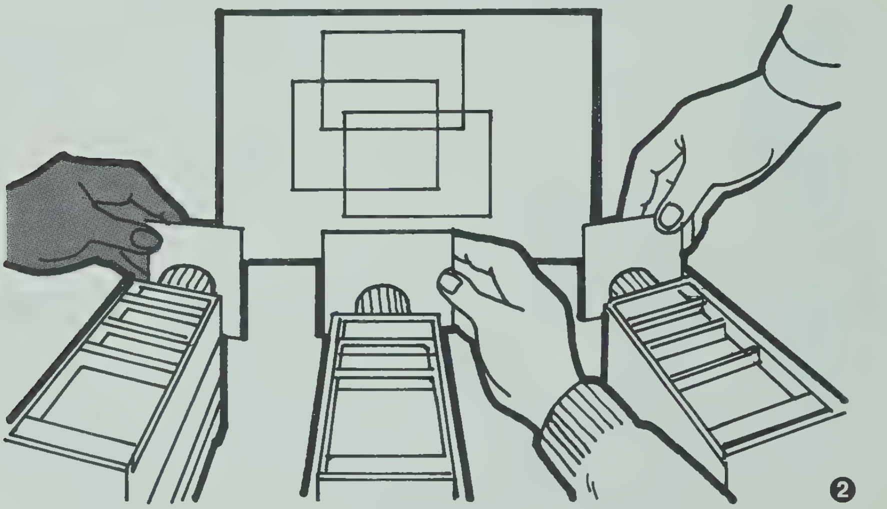
2. Now hold a red transparent square in front of one projector and a green transparent square in front of another projector. Aim part of one beam so it falls on part of the other beam. Notice the color where the red and green beams meet. ❶ Record the color you see (Table 1·7).

❶



Predict the colors that you will see by blending the other pairs of colored beams listed in the table. Try blending these beams and record your observations.

3. Add a third projector. Blend part of a blue beam with part of a red beam and part of a green beam. ❷ Make a drawing of the three beams in the space provided. Put the name of each color you see in the drawing you make.



Observing . . .

A. Table 1·7

Color of light beams	Color of blended light	
	prediction	observation
Red + Green	Variable	Yellow
Red + Blue		Magenta
Green + Blue		Cyan
Red + Green + Blue		White

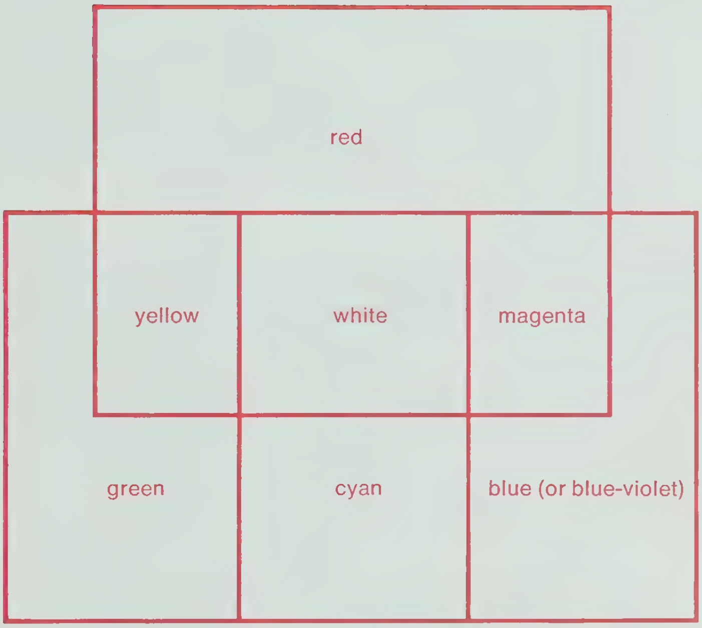
The answers provided represent the *ideal*. Allow for variation in student answers.

It will be difficult for students to obtain a "pure" white. Student results will be affected by the type of filters used and by the order in which the colored beams are arranged.

Name ______________________

Date __________ Class __________

B. Drawing of beams.



Interpreting . . .

1. Explain any differences between what you predicted and what you observed.

   Variable

2. Suppose you had three projectors and red, blue, and green filters. Describe how you would use the filters to produce (a) a yellow spotlight, (b) a white spotlight.

   (a) Use a red and a green filter to produce a red and a green light beam. Overlap the two beams to produce a yellow spotlight. (b) Use a red, a green, and a blue filter to produce a red, a green, and a blue light beam. Overlap the three beams to produce a white spotlight.

Tying ideas together:

Describe how mixing yellow, cyan, and magenta chalk is different from blending red, green, and blue light.

When yellow, cyan, and magenta chalks are mixed, a grayish color is produced. When red, green, and blue lights are blended, white is produced.

Now read "What is it about a tomato that makes it red?" and "Mixing lights," pages 14–15 and 22–23 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Mix chalk of two colors to produce a third color.
2. Describe what happens when colored chalks (or paints) are mixed.
3. Blend light of two colors to produce a third color.
4. Predict what will happen if light of given colors is blended.
5. Distinguish between blending red, green, and blue lights and mixing yellow, cyan, and magenta chalk or paints.

Name ____________________

Date __________ Class __________

CHAPTER 2: MIRROR REFLECTIONS

BEFORE YOU BEGIN PROBLEM A . . .

Read "Mirror Reflections," page 32 in your text.

Then pick up a flat mirror and a "two-way" mirror. Hold each mirror at a distance and look at your image. Bring each mirror close to your face and look again. Notice what else you see in the two-way mirror besides your face. Now think about these questions:

—Where does your mirror image seem to be located?

—Why isn't your right eye the right eye of your mirror image?

PROBLEM A: *What happens when light beams are reflected off the surface of a flat mirror?*

Materials:

1 Flashlight
1 Ruler
1 Piece of white paper
1 Mirror support (or modeling clay)
1 Protractor
  (Turn to page 263 for cutout P.)
1 Flat mirror
1 Flashlight mask, with slit 1-mm wide
  (Turn to page 263 for cutout B.)

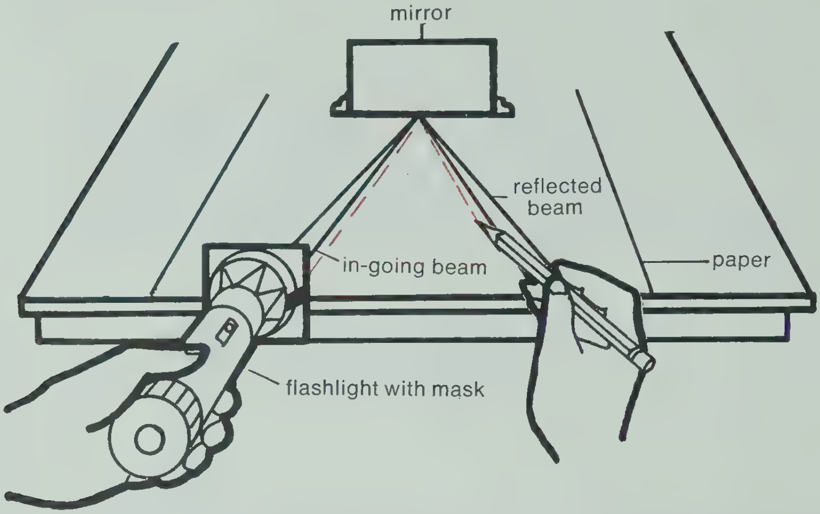
Investigating . . .

1. Cut out the paper mask labeled *B*. Make a slit in the center. Attach the mask to the front of your flashlight. Then cut out the protractor labeled *P*.

2. Support your mirror on a piece of white paper. Place the mirror parallel to the table edge. Draw a line along the bottom of the mirror.

3. Aim the flashlight beam along the table top so it hits the mirror and bounces off at an angle. With a pencil, trace the path of the in-going or *incident* light beam. Trace the path of the out-going or

reflected beam. Mark the point where the beam hits the mirror and bounces off. ❶



❶

4. Remove the mirror. At the point you marked, use the protractor to construct a line that is at an angle of 90° to the mirror. This line is called the *normal.* ❷

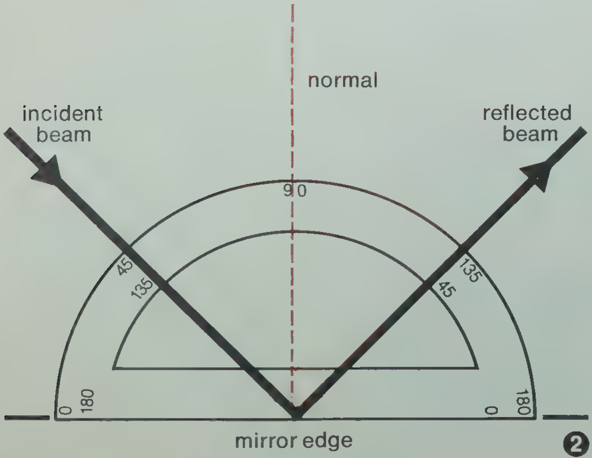
Note: Turn to page 245 to find clues for drawing and measuring angles.

Demonstrate how to use a protractor to find: (a) the normal, (b) the angle of incidence, and (c) the angle of reflection.

Refer students having trouble with the use of the protractor to page 245 in the Appendix.

5. Measure the size of the angle between the normal and the reflected beam. Record the angle size in Table 2·1. This angle is called the *angle of reflection.*

6. Measure the size of the angle between the normal and the incident beam. Record the angle size in Table 2·1. This angle is called the *angle of incidence.* ❸



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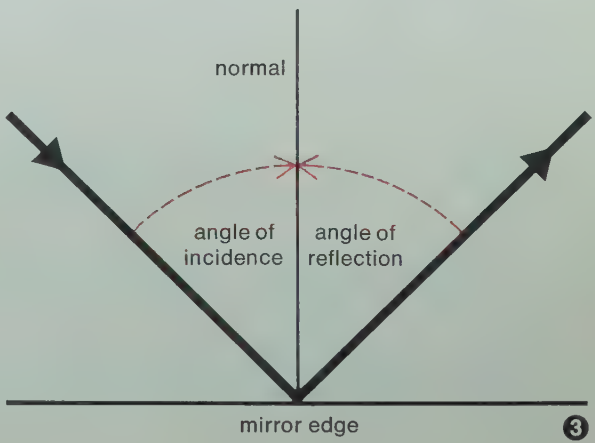

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Name ____________________

Date __________ Class __________

Repeat the activity two more times. Each time aim the flashlight beam so it hits the mirror and bounces off at a different angle. Record the angles of incidence and angles of reflection in Table 2·1.

Observing . . .

Table 2·1

Trial	Angle of incidence	Angle of reflection
1	Variable	Variable
2	The angle of incidence	should equal the
3	angle of reflection.	

Interpreting . . .

1. How does the angle of incidence compare with the angle of reflection in each trial?

   The angle of incidence is the same as the angle of reflection.

2. Try to state a rule that describes reflection of light off a flat mirror. Use your observations in Table 2·1.

   The angle formed by the incident light beam equals the angle formed by the reflected light beam.

Before you continue, read "What do you see in a mirror?" and "How does a mirror reflect light?" pages 33–35 in your text.

Name ______________________

Date ____________ Class ____________

PROBLEM B: ***What kind of image is made by a flat mirror?***

Materials:
- 1 Ruler
- 1 Piece of white paper
- 1 Mirror support (or modeling clay)
- 2 Nails, same size
- 1 Flat mirror, two-way

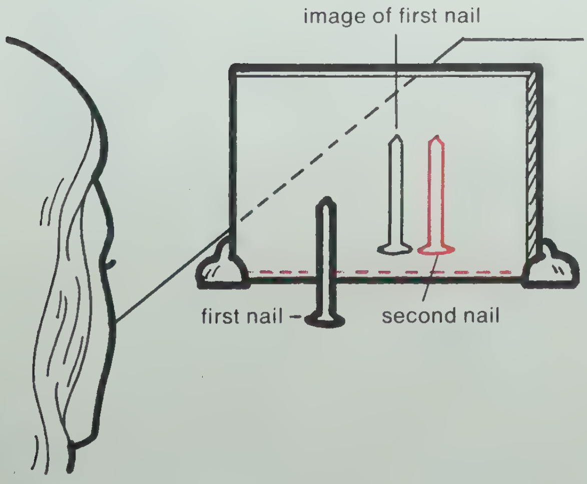
Investigating . . .

1. Put a two-way mirror on a piece of paper. Draw a line along the bottom of the mirror.

2. Place one nail in front of the mirror and another nail behind the mirror. Look into the mirror. You should be able to see *both* nails. ❶

3. Now comes the tricky part. Move the second nail around until it is *exactly in line* with the image of the first nail. If you've done it right, you should see only one nail—no matter where you look into the mirror from your side. ❷ You can assume that the real nail, behind the mirror, represents the size and apparent location of the image you see in the mirror now.

4. Mark the position of both nails and remove them. Measure the distance between the mirror and the first nail, and between the mirror and the second nail. Record the distance in Table 2·2.



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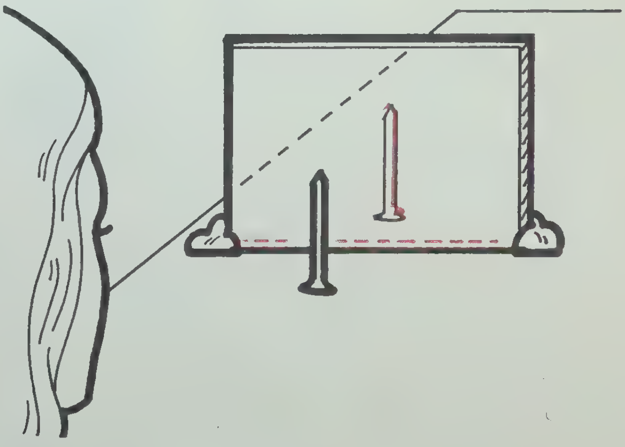

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Refer students having trouble with the use of the metric ruler to page 237 in the Appendix.

Note: Turn to page 237 to find clues for measuring length in centimeters (cm).

5. Notice whether the image is upright or upside down. Also notice if the nail and its image are the same size. Record your observations in Table 2·2.

Place the nails at other distances from the mirror. Record your distance measurements in the same table.

Observing . . .

Table 2·2

Trial	Location of object (nail #1) from mirror	Location of image (nail #2) from mirror	Image position (upright or upside down?)	Image size (large, small, or no change?)
1	Anyplace in front of the mirror.	Equal distance behind mirror	Upright	Same as object (no change)
2				
3				

Interpreting . . .

The image you see in a flat mirror is called a *virtual* image. A virtual image *cannot* be projected from a mirror onto another surface.

1. Does the virtual image seem to be located in front of the mirror or behind the mirror? How do you know?

   The virtual image is located the same distance behind the mirror as the object is located in front of the mirror. The distances from nail #1 to the mirror and from nail #2 to the mirror are equal.

Name ______________________

Date __________ Class __________

2. You place an object 30 cm in front of a flat mirror. Predict where the virtual image will seem to be.

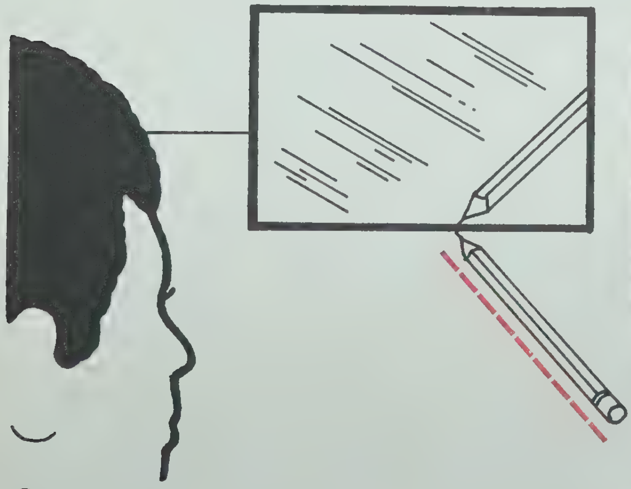
   The image will seem to be located 30 cm behind the mirror.

3. Describe a virtual image made by a flat mirror. Include the location, position, and size of the image in your description.

   A virtual image appears to be located behind the mirror. The image is upright and the same size as the object.

YOUR TURN: ***Is an image reflected in the same way as a light beam?***

Place a pencil at an angle to a mirror. One end of the pencil should touch the mirror. Lower your head until your eyes are level with the paper. Look at the image of the pencil. ❶ Take a second pencil and put it in line with this image. Draw a line along the angle formed by the two pencils. ❷ By the way, where is the image of the second pencil?



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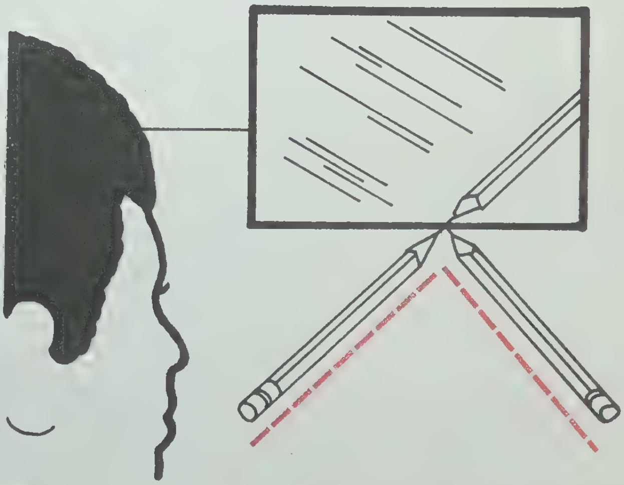


❷

Do you think the angle of incidence is the same as the angle of reflection? How would you find out?

Yes, the angle of incidence equals the angle of reflection. Students can find the normal, then measure the angle of incidence and the angle of reflection.

Before you continue, read "Apply the rule of reflection to a mirror image," pages 38–41 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Construct the angle of incidence and the angle of reflection for a light beam, given a flat mirror and a protractor.

2. Perform an experiment that demonstrates the rule of reflection for any flat mirror.

3. Perform an experiment that demonstrates three properties of virtual images made by a flat mirror.

Name ______________________

Date __________ Class __________

BEFORE YOU BEGIN PROBLEM C . . .

Hold a curved mirror (a shiny spoon will do) about 25 cm away from your face. Look at the side of the mirror that curves inward. This side of the mirror is called a *concave* mirror. Describe the image of your face in the concave mirror. Is it larger or smaller than life size? Wink your right eye. Which eye of the image winks back? What happens to the size and shape of your face as you move the mirror closer? Wink your right eye again. What happens? Now think about these questions:

—How is your image reflected off the surface of a concave mirror?

—When is your image located "behind" a concave mirror and when is it located in front?

—How can a concave mirror be used to cast an image onto a screen?

PROBLEM C: ***How are light beams reflected off the surface of concave mirrors?***

Materials:

1 Flashlight
1 Piece of white paper
1 Ruler
1 Thin aluminum sheet (10 cm x 7 cm)
1 Mask with five slits
(Turn to page 263 for cutout C.)
Modeling clay

Any other kind of shiny metal sheeting can be substituted for the aluminum.

Investigating . . .

1. Cut out the paper mask labeled C. Make five slits in your mask. Tape this mask to the front of your flashlight.

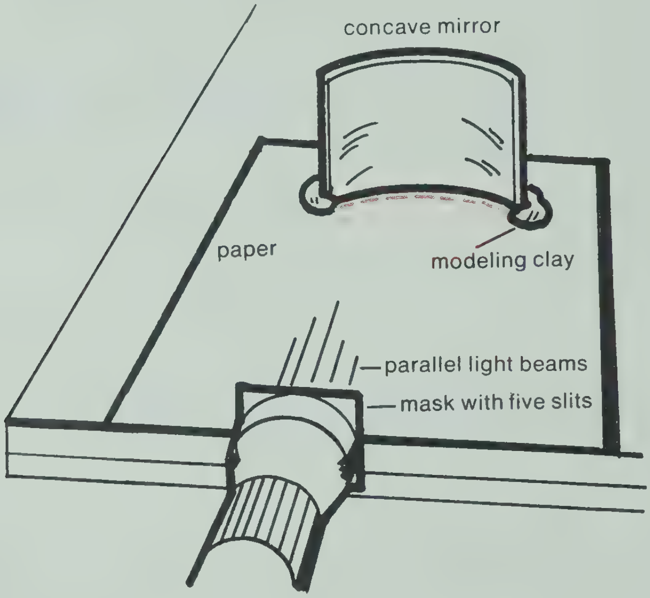
2. Now put a piece of white paper near the edge of the table. Hold the flashlight against the edge of the table, so that you get five parallel beams of light on the paper.

Check to make certain that students can project parallel beams of light on the paper. If not, it will be difficult for them to find the focal point of the mirror.

3. Make an inwardly curved, or *concave,* mirror by bending an aluminum sheet with your hand.

4. Put your concave mirror on the paper, about 10 cm away from the table edge. Hold the mirror in place with two pieces of modeling clay. Draw a line around the edge of the mirror.

5. Shine the parallel light beams at the center of the mirror. You should be able to see the in-going and out-going beams on the paper. Draw what you see in the space provided.



Refer students who are still having trouble with the use of the metric ruler to page 237 in the Appendix.

6. Mark the point where you see all the reflected beams meet. This point is called the *focal point* of the mirror. The distance from the center of the concave mirror to its focal point is the *focal length.* Measure the focal length and record it in Table 2•3.

Curve the metal sheet either more or less than you did before. Repeat the activity to find the focal length of your new concave mirror. Record your measurements in Table 2•3.

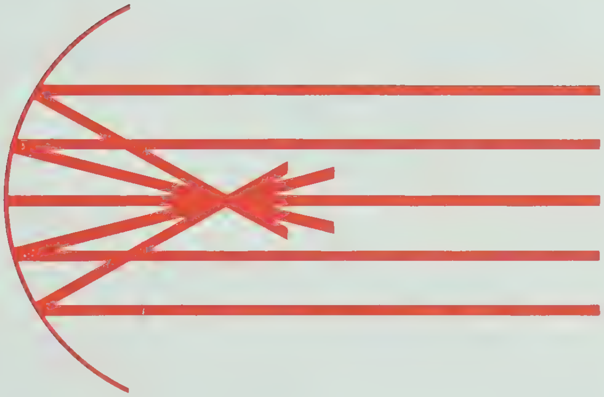
Make several more concave mirrors of different sizes. Find and record the focal length of these mirrors.

Name ____________________

Date __________ Class __________

Observing . . .

A. Your drawing of a concave mirror with incident (in-going) and reflected (out-going) beams:



B. Table 2·3

Concave mirror	Focal length	Concave mirror	Focal length
Curve #1	Variable—depends on the size of the curve	Curve #3	Variable
Curve #2		Curve #4	

Interpreting . . .

1. Describe what happens when parallel light beams hit a concave mirror.

   The beams are reflected at an angle. All the beams come together at the focal point of the concave mirror.

2. As you increase the curve of a concave mirror, how do you change the focal length?

   The focal length becomes shorter as you increase the curve of the concave mirror.

Before you continue, read "Mirror curves and reflections," pages 44–46 in your text.

Name ______________________

Date __________ Class __________

PROBLEM D: ***What kinds of images are made by concave mirrors?***

Materials:
1 Flashlight
1 Ruler
1 White index card
1 Mirror support (or modeling clay)
1 Round concave mirror
1 Mask with two arrow cutouts
(Turn to page 263 for cutout D.)

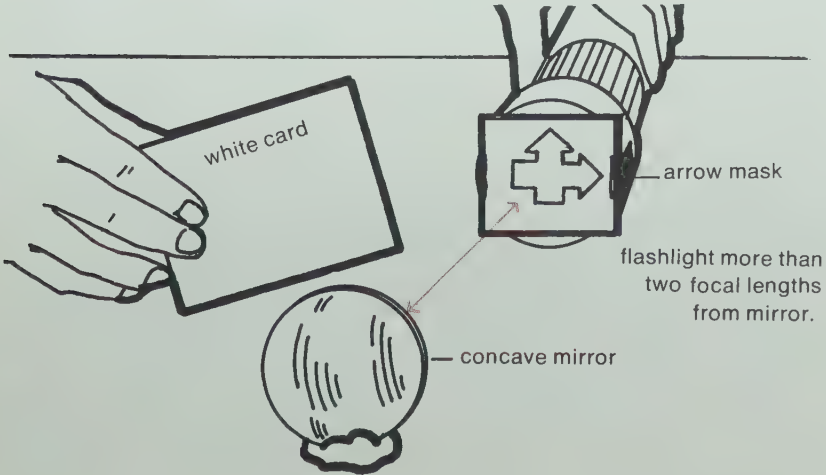
I Investigating . . .

Find out what kind of image an object makes when it is more than one focal length from a concave mirror:

1. Cut out the paper mask labeled *D*. Then cut out two arrows in the center of the mask. Attach the mask to a flashlight.

2. Put a round concave mirror in a holder. Aim the flashlight at the mirror. Move a white card around, near the mirror, until you see the image of the arrows on the paper. This image is called a *real* image. It can be projected from a concave mirror onto another surface.

3. Move the flashlight closer to the card, until the arrow images are the same size as the real arrows. Measure the distance from the mirror to the flashlight, and from the mirror to the image. Record your measurements in Table 2·4.


white card
arrow mask
flashlight more than two focal lengths from mirror.
concave mirror

Each measurement you just recorded in the table equals twice the focal length of the mirror or 2 F. To find the focal length of the mirror or F, divide 2 F in half.

4. Hold the flashlight at each place listed in Table 2•4. Record the location of the image. (Is the image at 2 F, beyond 2 F, or between F and 2 F?) Record the position of the image. (Is the image upright or upside down?) And record the size of the image. (Is the image enlarged, reduced, or the same size as the object?)

If F has been accurately pinpointed, *no image* will be projected. However, a very enlarged image will be projected at the focal point located by student if he or she has overestimated the distance of 2 F.

Observing . . .

Table 2•4

2 F_____ cm F_____ cm

Location of object (flashlight)	Location of image	Position of image	Size of image
At 2 F	2 F	Upside down	Same as object
At F	No image		
Between F and 2 F	Beyond 2 F	Upside down	Enlarged
Beyond 2 F	Between F and 2 F	Upside down	Reduced

Interpreting . . .

1. What kind of image (real or virtual) is made when an object is more than one focal length from a concave mirror? How can you tell if an image is real or virtual?

   Real. If the image is real, it can be projected onto a surface.

2. Describe how real images formed by a concave mirror can be made to change in size and location.

   The image is the same size as the object when the object is at 2 F, and the image is upside down. As the object is moved closer to the mirror (or F), the image grows larger, but remains upside down. As the object is moved away from the mirror (or beyond 2 F), the image grows smaller.

Name ____________________

Date __________ Class __________

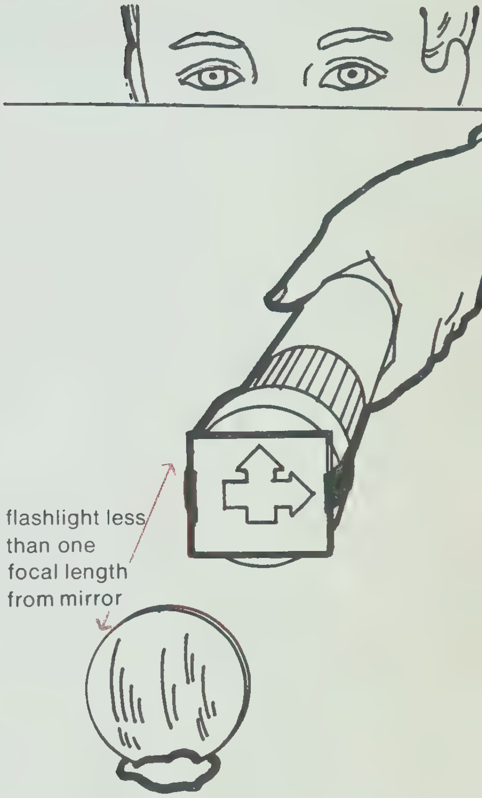
II **Investigating . . .**

Now find out what kind of image is made when the object is less than one focal length from a concave mirror.

1. Hold the flashlight just inside F. Try to make an image of the arrow cutouts appear on a card.

2. Move the flashlight a little closer to the mirror. Try again. (Remember, a virtual image cannot be projected onto another surface.) Write down your observations in the space provided.

3. Look into the mirror at the image of the arrows. Notice if the image is upright or upside down. Record your observations in Table 2•5.


flashlight less than one focal length from mirror

Observing . . .

A. What happens if you try to project an image of the arrows when the arrows are less than one focal length from the concave mirror?

Nothing. No image can be projected.

B. Table 2•5

Position of object	Inside F
Location of image	Behind or "in" the mirror
Position of image (upright or upside down)	Upright
Size of image	Enlarged

Interpreting . . .

1. What kind of image (real or virtual) is formed by an object when the object is less than one focal length from a concave mirror? How do you know?

The image is virtual because it cannot be projected.

2. Describe the image made by an object which is less than one focal length from a concave mirror. Include location, size, and position of the image in your description.

   The image is located behind the mirror. It is upright and enlarged.

Tying ideas together:

1. Name two kinds of images made by a concave mirror. How would you produce each kind of image?

   Virtual and real images. To produce a virtual image, hold the object inside F. To produce a real image, hold the object outside F.

2. In what ways is the virtual image of a concave mirror different from the virtual image of a flat mirror?

   The virtual image of a flat mirror is the same size as the object, no matter where the object is held from the mirror. The virtual image of a concave mirror is enlarged. The virtual image can only be produced when the object is inside F.

Now read "What's the larger-than-life image you see?" and "Things turned upside down," pages 46–49 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Use parallel beams of light to find the focal point of a concave mirror.
2. Calculate the focal length of a concave mirror, given the mirror position and 2 F.
3. Use a concave mirror to produce virtual and real images.
4. Perform an experiment that demonstrates three properties of real images made by a concave mirror.
5. Perform an experiment that demonstrates three properties of virtual images made by a concave mirror.

Name ____________________

Date __________ Class __________

CHAPTER 3: IMAGES THROUGH A PINHOLE

BEFORE YOU BEGIN PROBLEM A . . .

Read "Images Through a Pinhole," page 54 in your text.

Then make a special viewing box. Start by cutting a hole in one end of a shoe box. The hole should be just big enough for the head of your flashlight to fit through. Mark off the length (inside) of the shoe box in centimeters.

Refer students having trouble with the use of the metric ruler to page 237 in the Appendix.

Tape your arrow cutout mask to the flashlight (see Problem D, page 31). Push the flashlight backwards through the opening in the box.

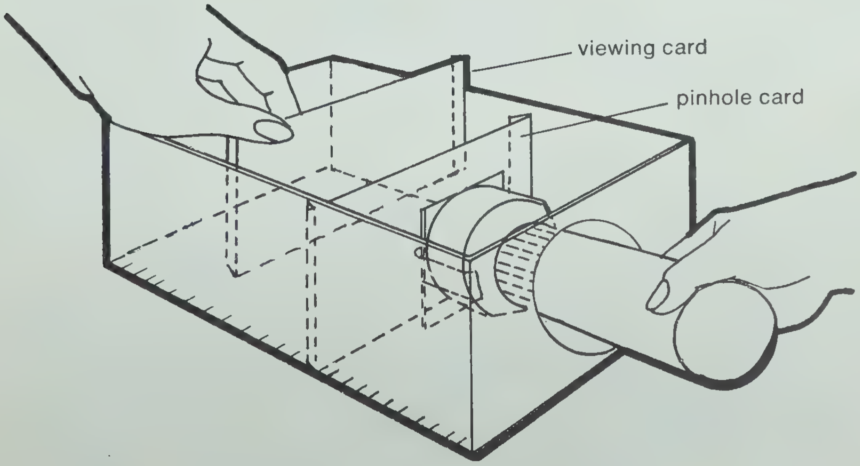
Stand a card about 5 cm in front of the flashlight beam. Make a small pinhole where the light beam hits the card. Put another card *behind* the card with a pinhole.

Now you're ready to begin: The classroom should be darkened. Cover your head and the box with a dark cloth. Move the two cards around until you see an image of the arrows on the second card. Then think about these questions:

—Does light seem to travel in a straight line through a pinhole?

—What kind of image is produced by a pinhole?

—How can the size of a pinhole image be changed?



PROBLEM A: ***How do you make different kinds of pinhole images?***

Materials: 1 Flashlight
1 Shoe box
1 Ruler
2 White cards, 7 cm × 25 cm
1 Dark cloth
1 Pin
1 Flashlight mask with two arrow cutouts
(See Problem D, page 31.)

A dark, opaque cloth must be used to darken the box—otherwise the image will be too dim to see.

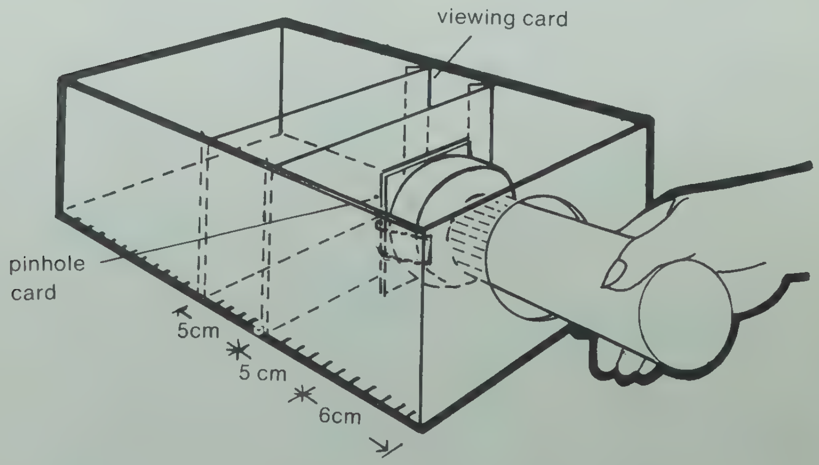
Investigating . . .

Use your viewing box to learn more about pinhole images.

1. Push the flashlight to the 6-cm mark in the shoe box. Stand the pinhole card 5 cm in front of the flashlight. And stand the viewing card 5 cm behind the pinhole card.

2. Cover the box and your head with a cloth. Slowly move the *pinhole card* away from the flashlight. Describe the change in size, sharpness, and brightness of the arrow images in the space provided.

3. Now slowly move the pinhole card toward the flashlight. Again, describe the change in size, sharpness, and brightness of the arrow images.



Name ____________________

Date __________ Class __________

4. Next, slowly move the *viewing card* away from the pinhole card. Then move the viewing card toward the pinhole card. In each case, describe what happens to the arrow images.

Observing . . .

A. What happens to the arrow images when your *pinhole card* is moved back and forth in front of the flashlight?

The image becomes larger, blurred, and faint as the pinhole is moved closer to the light. It becomes smaller, very sharp, and bright as the pinhole is moved away from the light.

B. What happens to the arrow images when your *viewing card* is moved back and forth behind the pinhole card.

The image becomes smaller, very sharp, and bright as the viewing card is moved closer to the pinhole. It becomes larger, blurred, and faint as the screen is moved away from the pinhole.

C. Compare the image of the arrows to the real arrows on the mask. Is the image reversed in any way?

The image is reversed and upside down.

Interpreting . . .

1. How would you produce a large pinhole image?

   Move the pinhole card close to the flashlight or move the viewing card away from the pinhole card.

2. How would you produce a small, bright pinhole image?

   Move the pinhole card away from the light or move the viewing card closer to the pinhole card.

3. Is a pinhole image real or virtual? How do you know?

   Real. The image can be projected.

YOUR TURN: ***What happens to the size of a pinhole image if the size of the pinhole is changed?***

Do an experiment of your own to find out what happens to the size of the pinhole image if the size of the pinhole is increased. Write down what you think will happen. Briefly describe what you did to find out and record your results.

Before you continue, read "Catching an image through a pinhole," pages 55–57 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Use a box, pinhole, and flashlight to produce pinhole images.
2. Make predictions about the size, sharpness, and position of pinhole images, given image distance, object size, and object distance.

Name ______________________

Date __________ Class __________

CHAPTER 4: LENSES

BEFORE YOU BEGIN PROBLEM A . . .

Read "Lenses," page 67 in your text.

Then stand at your classroom window. Hold a white card in one hand and a *double-convex lens* in the other hand. A double-convex lens is a round piece of glass or plastic that curves out on both sides. Move the lens around until you see an outdoor scene on your card. Notice how the scene on your card is different from what you actually see outside. Notice how the scene is similar.

If there are no windows in the classroom, dim the room and have students use a double-convex lens to try and project a bright scene outside their classroom door onto a piece of paper.

Hold the same lens close to a page in your laboratory book. What do you see now? Think about these questions:

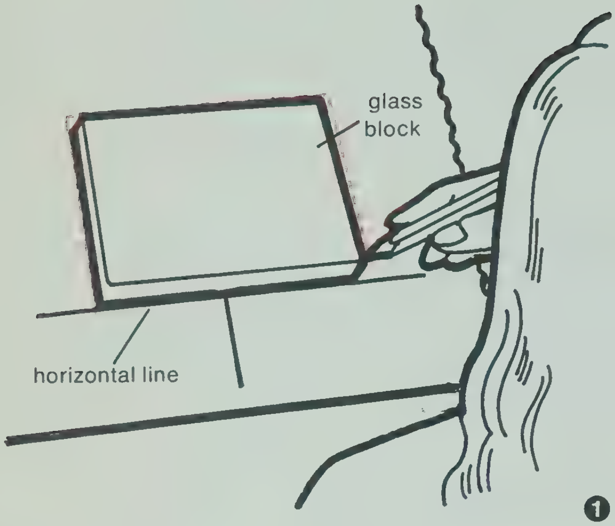
—What happens to light when it passes from air through another substance?

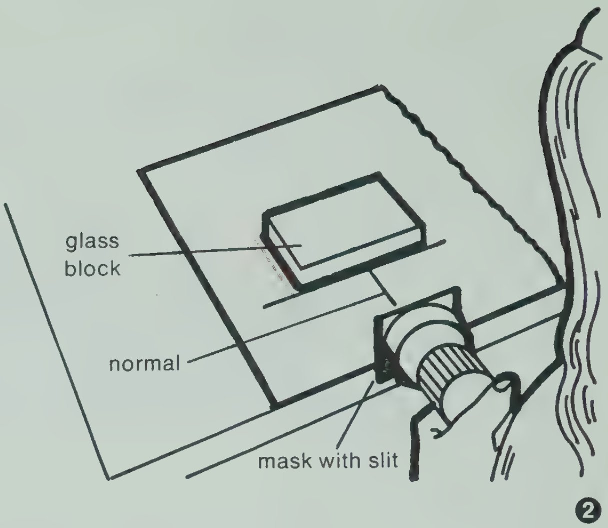
—What happens to light when it passes through a lens?

—How are lenses similar to concave mirrors?

PROBLEM A: ***What happens to a beam of light as it moves from air into another substance?***

Materials:
1 Flashlight
1 Mask with slit (See Chapter 2, Problem A)
1 Glass block
1 Square plastic container
1 Protractor (See Chapter 2, Problem A)
Distilled water





Investigating . . .

Demonstrate the procedure for this activity.

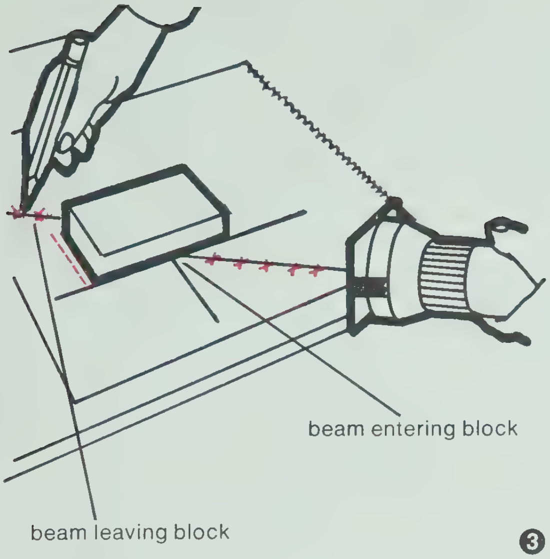
1. Tear out the "Observing . . ." page labeled "GLASS." Place the edge of a glass block on the *horizontal line* drawn on that page. Draw a line around the block. ❶ Then place the mask on your flashlight.

2. Use a beam of light to hit the block along the *vertical line* drawn on the same page. Notice that this beam passes straight through the block. The vertical line is called a *normal*. ❷

3. Now use a beam of light to hit the block along the angle drawn on the page. Make X's on the page to trace the path of the beam as it travels through the air from the flashlight to the block.

4. Next make X's on the page to trace the path of the beam as it leaves the glass block and again passes into the air. ❸

5. Finally, remove the glass block. Use a ruler to connect the two beams. The line you have drawn is the path of the beam as it passes through the glass block.



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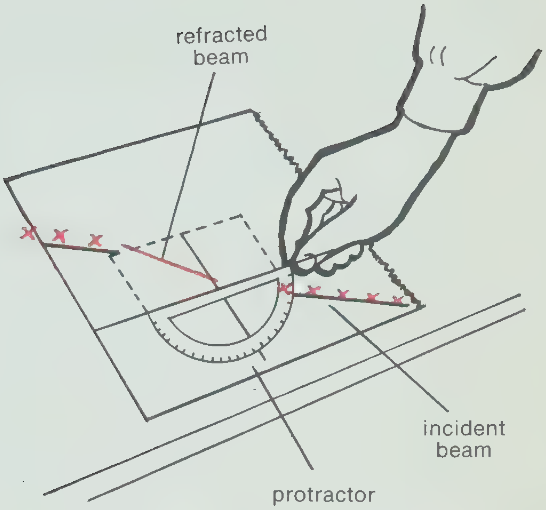


❹

The in-going beam is called the *incident beam.* The path of the beam as it goes through the glass is the bent or *refracted beam.*

The angle between the incident beam, entering from the air, and the normal is an *angle of incidence.* The angle between the refracted beam, after it enters the glass, and the normal is an *angle of refraction.*

6. Using the protractor, measure the angle of incidence and the angle of refraction. Record these two angles in the space provided. ❹

Demonstrate how to use the protractor to find the angle of incidence and angle of refraction.

Note: Turn to page 245 to find clues for drawing and measuring angles.

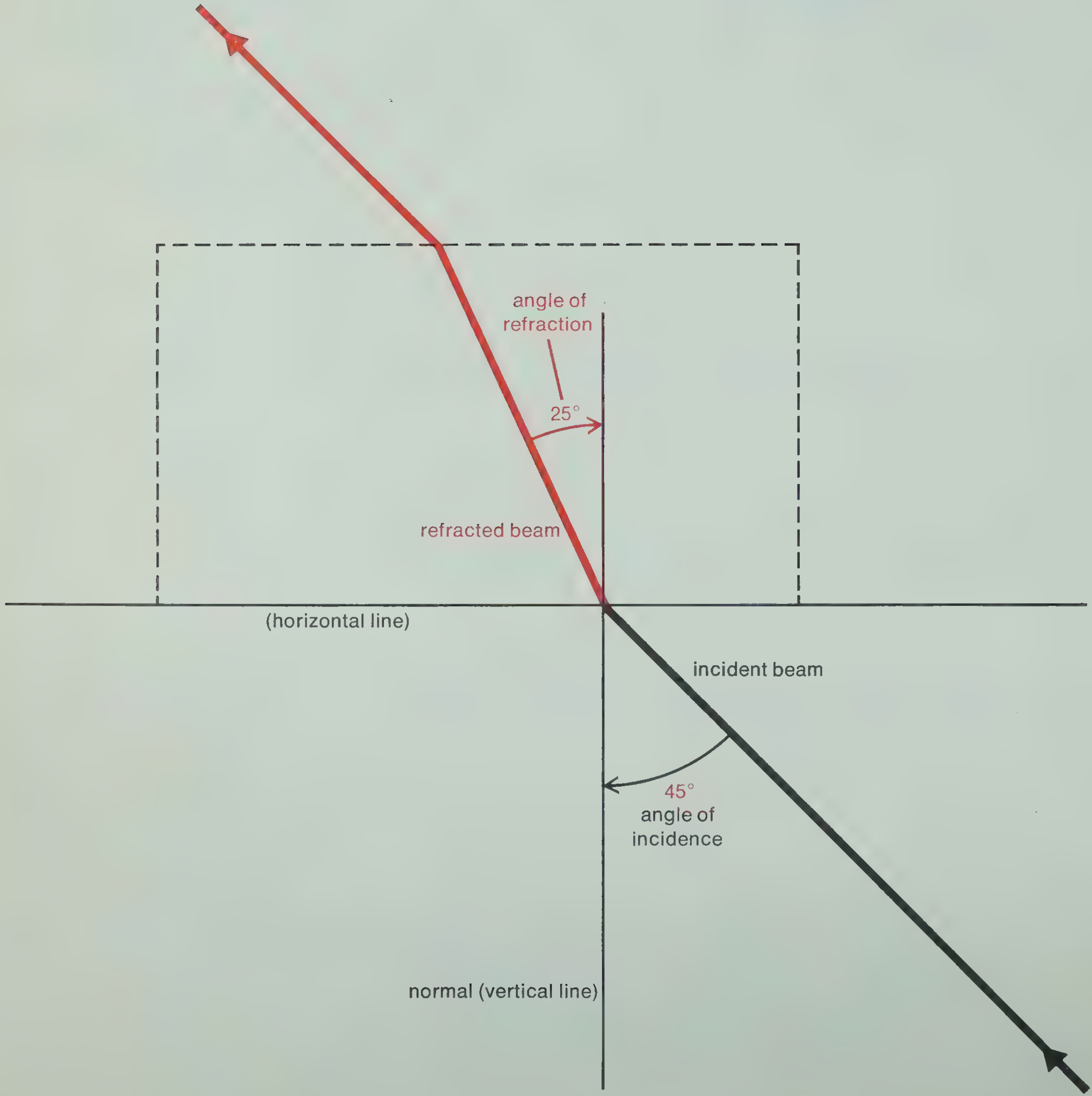
Refer students having trouble with the use of the protractor to page 245 in the Appendix.

Repeat the activity. But this time, tear out the "Observing . . ." page labeled "WATER." Find the angle of incidence and the angle of refraction for a light beam as it passes through a container of *water.* Record your measurements.

Fill clear plastic containers with distilled water.

Observing . . .

A. GLASS



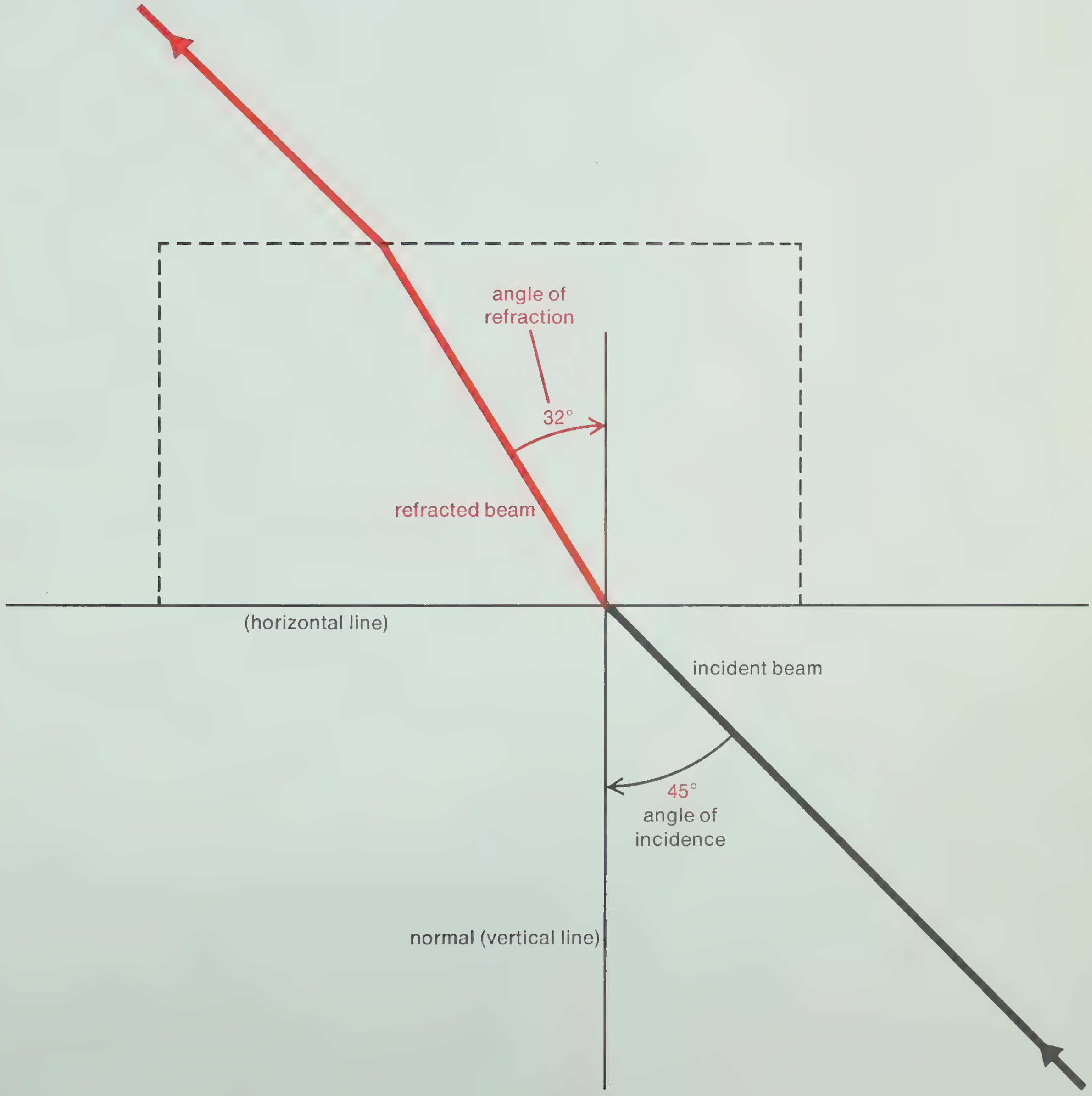
Glass:
Angle of incident beam 45°
Angle of refracted beam 25°

Results will vary, since student measurements will not be accurate. These answers are only approximate.

Name ____________________

Date __________ Class __________

B. WATER



Water:

Angle of incident beam 45°

Angle of refracted beam 32°

Interpreting . . .

Check the correct answer in questions 1 and 2:

1. The angle of incidence and angle of refraction are:
   ________ about the same, ___X___ different.

2. The angles of refraction for glass and water are:
   ________ the same, ___X___ different. What might be some reasons why you think so?

   Light is bent or refracted at different angles when it passes through different substances.

3. Describe what happens to light as it passes at an angle from air into another substance.

   Light bends (or changes direction) as it passes from air into another substance.

4. A spear fisherman is standing behind a tasty looking fish. He aims the spear directly at the fish. Will the spear hit the fish or miss it? Use your observations in this problem to explain your answer.

   Miss. Since light rays are bent as they pass from air to water, the fish appears to be in a different spot than it really is.

Before you continue, read "Angles of light" and "Angles of light in various materials," pages 68–71 in your text.

Name ____________________

Date __________ Class __________

PROBLEM B: ***What happens to light as it passes through a double-convex lens?***

Materials: 1 Flashlight
1 Shoe-box lid
1 Piece of white paper
3 Double-convex lenses, different focal lengths
1 Mask with 5 parallel slits
(See Chapter 2, Problem A.)

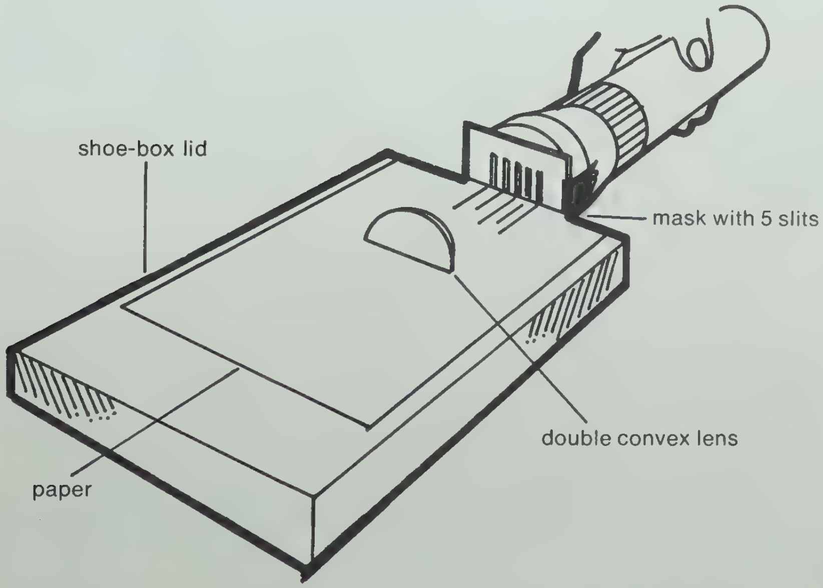
Investigating . . .

1. Pick out three double-convex lenses of different sizes. Label each lens with masking tape—#1,#2, and #3.

2. Make a lens holder by cutting a slot in the top of a shoe-box lid, about 5 cm from one end. Make the slot a little shorter than your lenses. Put a large piece of white paper on the shoe box. Cut a slit in the paper. Slide one of your lenses through the opening in the paper and into the slot.

3. Attach a mask with 5 slits to your flashlight. Keep the slits at a right angle to the filament in the bulb.

4. Hold your light at the edge of the lid, so parallel beams are thrown across the paper and pass through the lens. In the space provided, sketch the light beams before and after they pass through the lens.



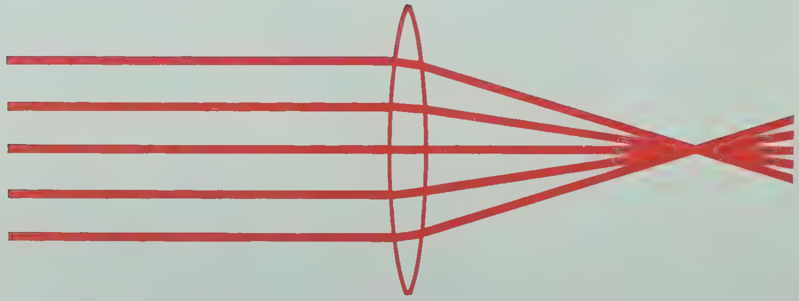
After passing through the lens, the beams of light meet at a point called the *focal point*. The distance from the center of the lens to the focal point is the *focal length*.

5. Measure the focal length of your lens, and record it in Table 4•1. Now turn the lens around. Find the focal length of the other side. Record this information in the same table.

Find the focal lengths of the other two lenses. Record their focal lengths in Table 4•1.

Observing . . .

A. Your drawing of parallel light beams before and after they pass through a double-convex lens:



Name ____________________

Date __________ Class __________

B. Table 4·1

Lens	Focal length side 1	Focal length side 2
#1	Variable	Variable
#2	The lens with the greatest curvature	
#3	will have the shortest focal length.	

Interpreting . . .

1. How many focal points does a double-convex lens have?

   Two.

2. How is the curve of a double-convex lens related to its focal length?

   The more curved the lens, the shorter its focal length.

3. Predict what you think will happen to parallel light beams when they pass through a drop of water. Use your observations to help you. (Hint: What kind of lens is formed by a drop of water?)

   A drop of water acts as a double-convex lens. The light beams will come together at the focal point of the water drop.

Before you continue, read, "Now onward with lenses," pages 78–79 in your text.

Name ________________________

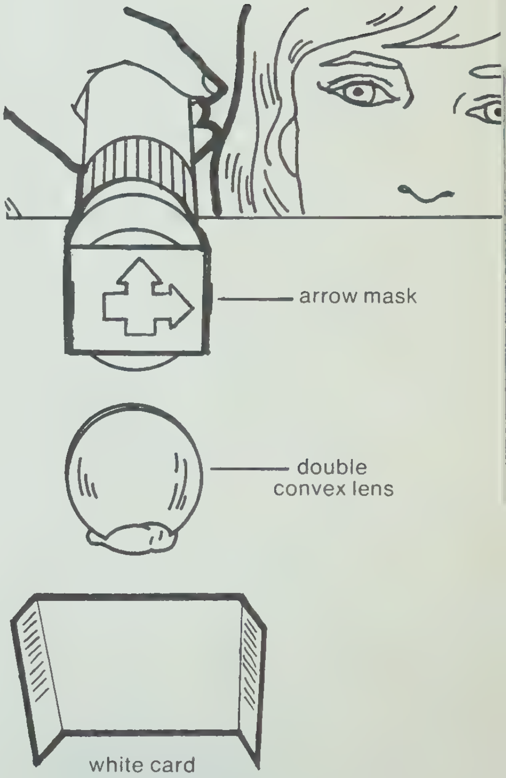
Date __________ Class __________

PROBLEM C: ***How are double-convex lenses used in cameras and as magnifiers?***

Materials: 1 Flashlight
1 Arrow mask (See Chapter 2, Problem D)
1 Double-convex lens
1 Lens holder (or modeling clay)
1 White card, 7 cm × 25 cm

Investigating . . .

1. Tape an arrow cutout mask to the end of your flashlight.
2. Support a double-convex lens in a lens holder. Place the lens and holder in front of a white card.
3. Aim the flashlight beam at the lens. Move the lens around until you see the image of the arrows on the card.



Now you're on your own. Find out what kind of images are formed by a double-convex lens. Make up your own experiment. If you need help, use the directions and the tables from Problem D. "What kinds of images are made by concave mirrors?" page 31.

Observing . . .

Interpreting . . .

1. What kind of image (virtual or real) is made by an object which is more than one focal length from a double-convex lens? How do you know?

   Real. The image can be projected. It is formed in front of the lens.

2. What kind of image (virtual or real) is made by an object which is less than one focal length from a double-convex lens? How do you know?

   Virtual. No image can be projected. The image is formed "inside" or behind the lens.

3. Now use your observations to explain how a double-convex lens could be used in a camera or as a magnifier.

   Variable

Now read "Camera images with double-convex lenses" and "Double-convex lenses as magnifiers," pages 80–82 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Find the angle of the incident beam at the flat surface of a glass block and of a container of water.
2. Find the angle of the refracted beam in a glass block and in a container of water.
3. Use experimental observations to describe what happens to light as it passes from air through another substance.
4. Use parallel beams of light to find the focal points of any double-convex lens.
5. Perform an experiment to demonstrate the kind of images made by a double-convex lens.

Name ____________________

Date __________ Class __________

CHAPTER 6: MEASURING ELECTRICITY

BEFORE YOU BEGIN PROBLEM A . . .

Read "Electricity" and "Measuring Electricity," pages 116–120.

Then take a battery, battery holder, bulb holders, and some wires with clips. Select bulbs of different sizes. Try to make each bulb light. Now think about these questions:

—What happens to the electric current when you turn on a lamp or a TV set?

—What makes some bulbs bright and others dim?

—How can you find out how much electricity a bulb uses?

PROBLEM A: *What is an electrical circuit?*

Materials:
- 3 Batteries, 1.5 volts
- 3 Wired bulb holders
- 3 Bulbs, 4.9 volts
- 3 Battery holders
- 12 Wires with clips at both ends

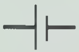
Use GE 13, 425, and 502 bulbs.

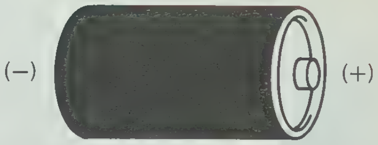
The bulb holders, batteries, and bulbs can be purchased at any hardware store. The 4.9-volt bulb is GE 425.

It may be helpful to demonstrate circuit diagrams on the blackboard.

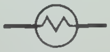
Investigating . . .

Here's a shorthand way to draw batteries and bulbs. Use symbols instead of pictures:

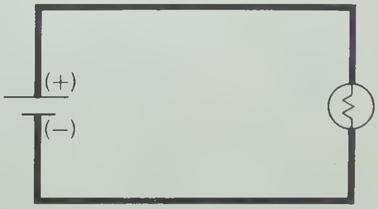
The symbol for a battery is  . The long line is the (+) end of the battery. The short line is the (–) end. On a flashlight battery, the (+) end has a bump in the center. ❶



❶

The symbol for an electric light bulb is  .

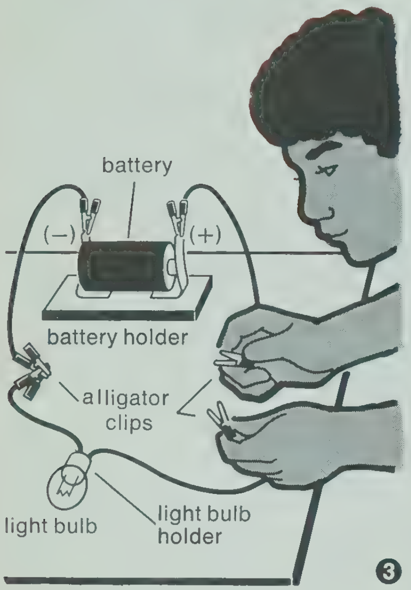
The complete path along which the electric current travels is known as a *circuit*. Figure ❷ is a diagram of a complete circuit with one battery and one bulb.



❷

Make certain that the batteries are fresh.

Check student setups to see that (a) batteries are in the correct position, (b) batteries are firmly in the holders, (c) bulb is firmly in the socket, (d) all wires are connected to make a complete circuit.



❸

Figure ❸ shows how the same circuit really looks.

1. Connect the first circuit listed in Table 6•1.
2. Make a diagram of the circuit.
3. Record the color of the light-bulb filament. Is the filament *white*, *yellow*, or *orange?*

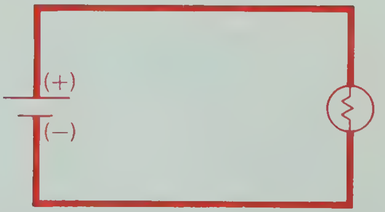
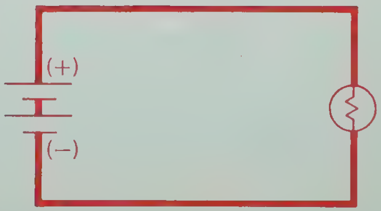
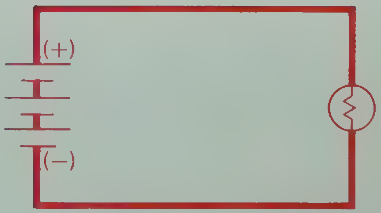
Now repeat the activity with all of the other circuits listed in Tables 6•1 and 6•2. For the circuits where more than one battery is used, hook the positive end of one battery to the negative end of the next battery.

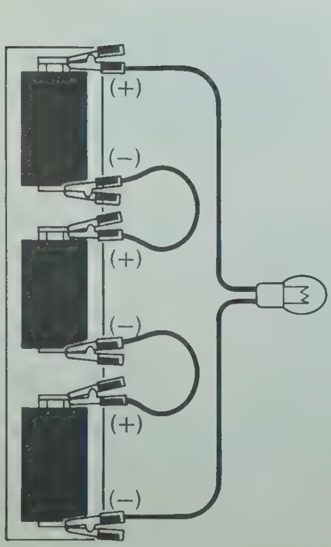
Observing . . .

Check to see that students are diagramming the circuits correctly.

Ask students to describe the battery setup when two or more batteries are used in a circuit.

Table 6•1: Circuits with *ONE* flashlight bulb

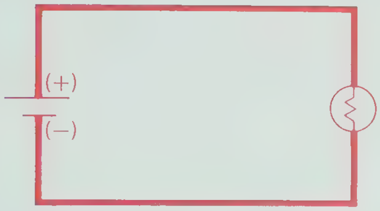
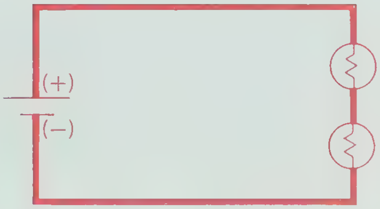
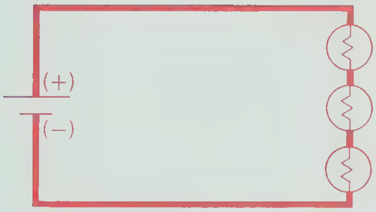
Number of batteries	Color of filament	Diagram of circuits
1	Orange or Yellow	
2	Yellow or White	
3	White	

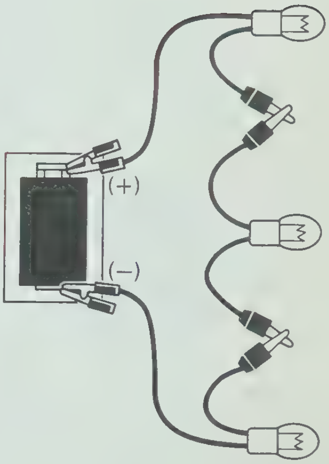


Name ____________________

Date ____________ Class ____________

Table 6·2: Circuits with *ONE* flashlight battery

Number of bulbs	Color of filament	Diagram of circuits
1	Orange or Yellow	
2	Orange	
3	No color or Faint Orange	



Interpreting . . .

1. What evidence do you have that electrical energy is being used in a circuit?

   The bulb lights.

2. What happens to the color of the filament in a 1-bulb circuit as the number of batteries is increased? Try to explain your observations.

   The bulb filament changes from orange to yellow to white as the batteries are increased. More batteries supply more current to the bulb.

3. What happens to the color of the filaments in a 1-battery circuit as the number of bulbs is increased? Try to explain what you have observed.

   The bulb filament turns orange and becomes faint as the bulbs are increased. Less current is supplied to each bulb as more bulbs are added to the circuit.

4. Describe a complete circuit.

   A complete circuit, in this activity, has a bulb that is connected to each end of a battery by wires with clips.

Name ____________________

Date __________ Class __________

PROBLEM B: *What determines the amount of electricity which moves through a circuit?*

Materials:
- 1 Ammeter, 0-1 amp
- 3 Batteries, 1.5 volts
- 3 Bulbs, 3.75 volts
- 1 Bulb, 4.9 volts
- 1 Bulb, 5.1 volts
- 3 Battery holders
- 3 Wired bulb holders
- 12 Wires with clips at both ends

Use GE 13, 425, and 502 bulbs.

Put bulbs of different voltages in separate containers so students are certain to take three *different* bulbs.

It may help students to note differences in the physical size and the filament size of the bulbs.

Use an ammeter to make the measurements in this problem. An ammeter measures the amount of electric current in units called amperes or *amps*. It is shown in shorthand drawings by —Ⓐ— .

I Investigating . . .

First of all, use your ammeter to find the electric current in a circuit containing different types of bulbs.

ALWAYS connect the (+) terminal of the ammeter toward the (+) end of the battery.

ALWAYS connect the (–) terminal of the ammeter toward the (–) end of the battery.

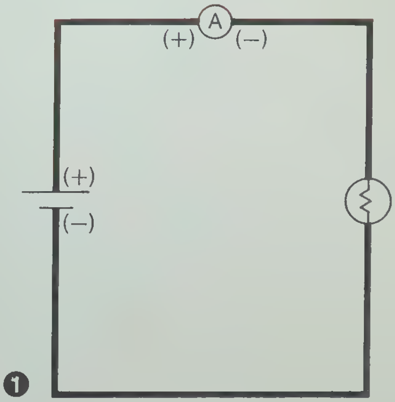
ALWAYS attach a user of electricity (bulb) in the circuit with an ammeter.

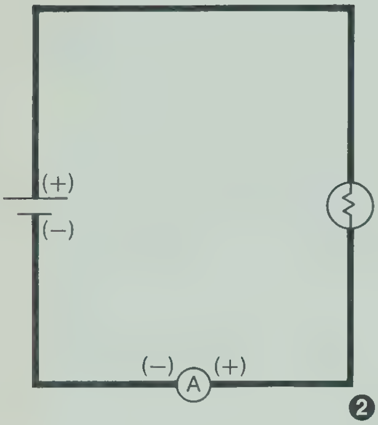
NEVER place an ammeter in a complete circuit alone. Otherwise, too much current will pass through the ammeter and break it.

Be certain to check student setups before any circuits are completed. The ammeter *must* be connected properly or it will be broken.

1. Take three bulbs that have different numbers on their bases. Record the numbers—from smallest to largest.
2. Attach your ammeter in a path or circuit with one battery and one bulb (bulb #1). ❶
3. Record the ammeter reading for the bulb in Table 6•3.

❶





❷

If students are having trouble judging the brightness of bulbs, they can use a waxed-paper scale. Have them cut strips of waxed paper 12, 10, 8, 6, 4, and 2-cm long. Put the strips on top of each other and attach them at one end. They can judge brightness by the number of layers through which each bulb can be seen.

4. Rate the brightness of the bulb on a scale from #1 to #5 (#1 to #3 = white, #4 = yellow, #5 = orange).

Repeat the activity with each of the other two bulbs in a circuit by itself.

5. Then attach the ammeter on the *other* side of bulb #3. ❷ Record the ammeter readings under C below.

Observing . . .

A. Write down the number on the base of each bulb.

Bulb #1 13, Bulb #2 425, Bulb #3 502

B. Table 6·3

Bulb size	Amps	Brightness of bulb
#1	Variable. GE 13 should have the	Variable. GE 13 should be the
#2	highest ammeter reading, GE 502	brightest, GE 502 the dimmest.
#3	the lowest.	

C. Ammeter reading on other side of bulb #3.

Same. There should be no variation in the ammeter reading.

Interpreting . . .

1. What happens to the ammeter reading in a circuit when different kinds of bulbs are used?

The ammeter reading changes when different kinds of bulbs are used.

2. Why do you think the ammeter readings compared as they did on both sides of bulb #3?

There was the same amount of current on both sides of the bulb.

Name ______________________

Date ____________ Class ____________

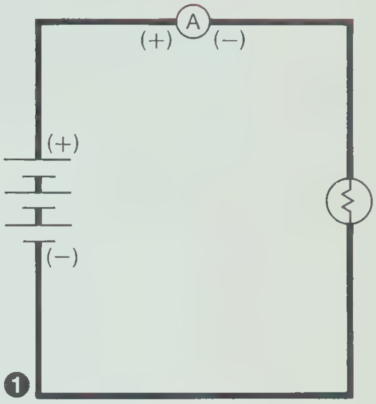
Again, the ammeters should be connected correctly.

II **Investigating . . .**

Use your ammeter to find the electric current in a circuit with one or more batteries.

1. Attach your ammeter in a circuit with one bulb and one battery. Use the bulb with the highest number on the base. Then add more batteries, one at a time. Connect the (+) end of one battery to the (−) end of the next. ❶ Record the ammeter readings, and rate the brightness of the bulb in Table 6•4 (#1 to #3 = white, #4 = yellow, #5 = orange).

2. Attach the ammeter between each of the three batteries. ❷ Record what the ammeter reading is between each battery.



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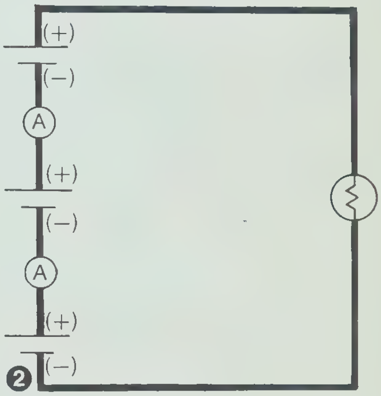


❷

Explain that the diagram shows both places where an ammeter is to be attached in the circuit. Two ammeters are not to be attached at the same time.

Observing . . .

A. Table 6•4

Number of batteries	Amps	Brightness of bulb
1	Variable. As more batteries are added, the amperage increases.	Variable. As more batteries are added, the bulbs become brighter.
2		
3		

B. Ammeter readings between battery 1 and 2 ________ amps; between battery 2 and 3 ________ amps.

Is there more electric current (amperage) in any part of the battery circuit?

No

The ammeter readings between the batteries will be the same as the reading for a circuit with three batteries and one bulb.

Interpreting . . .

What happens to the electric current in a circuit as more batteries are added?

As more batteries are added, the current in the circuit increases.

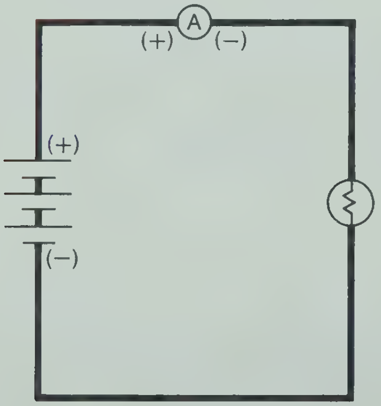
III Investigating . . .

Make certain that students have three bulbs of the same size—GE 13.

The ammeters should be connected correctly.

Now use the ammeter to find the electric current in a circuit when bulbs are added along one path.

1. Pick three #1 bulbs. Attach your ammeter in a path with three flashlight batteries and one of your bulbs. Record the ammeter reading, and rate the brightness of the bulb. ❶ Add more bulbs, one at a time. Record your observations in Table 6•5.



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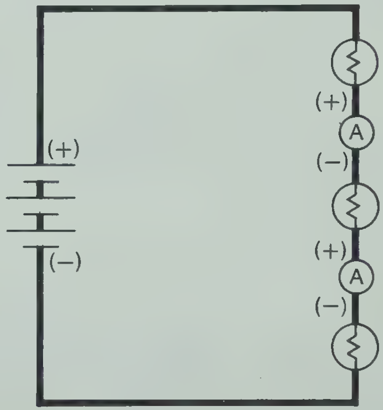


❷

2. Attach the ammeter between each of the three bulbs. ❷ Record the ammeter readings in the space provided *(B)*.

Name ______________________

Date ___________ Class ___________

Observing . . .

A. Table 6·5

Number of bulbs	Amps	Brightness of bulbs
1	Variable. As the number of bulbs increases, the ammeter reading decreases.	Variable. As more bulbs are added, the bulbs grow dimmer.
2		
3		

B. Ammeter readings between bulbs 1 and 2 ________ amps; between bulbs 2 and 3 ________ amps.

The ammeter readings between the bulbs will be the same as the reading for a circuit with three bulbs and three batteries.

Is the current different in any part of the circuit?

No

Interpreting . . .

What happens to the current in a circuit having one path as more bulbs are added?

As more bulbs are added to the circuit, the current in the circuit decreases.

Tying ideas together:

1. Is the current the same in all parts of a circuit having one path? Give evidence to support your answer.

Yes. No matter where the ammeter is placed in a circuit, the amperage is the same.

2. Describe a circuit setup that would give you (a) the largest ammeter reading, (b) the smallest ammeter reading.

   (a) Largest amperage: 1 bulb #13, three batteries.
   (b) Smallest amperage: 3 bulbs #502, one battery.

Before you continue, read "A mental model" and "An electrical path," pages 121–126 in your text.

Name ______________________

Date __________ Class __________

PROBLEM C: ***Why are some lights bright and others dim?***

Demonstrate how a voltmeter is connected in a circuit, as compared with how an ammeter is connected in a circuit.

Check to be certain all students have three bulbs of the same size—#13.

Check the voltmeter and ammeter setups of each student.

Refer students to Problem B, page 56, for the method of rating the brightness of bulbs.

Materials:	
	3 Batteries, 1.5 volts
	3 Bulbs, 3.75 volts
	1 Bulb, 4.9 volts
	1 Bulb, 5.1 volts
	3 Wired bulb holders
	3 Battery holders
	1 Voltmeter, 0-8 volts
	12 Wires with clips

You are going to measure the voltage across bulbs in electric circuits. Use a *voltmeter* to take the measurements. A voltmeter measures in units called *volts*. It is shown in a shorthand drawing by —Ⓥ—.

To find how much voltage is used by each bulb, attach one wire of the meter to *each side* of the bulb.

ALWAYS attach the (+) terminal of the voltmeter toward the (+) end of the battery.

ALWAYS attach the (–) terminal of the voltmeter toward the (–) end of the battery. ❶

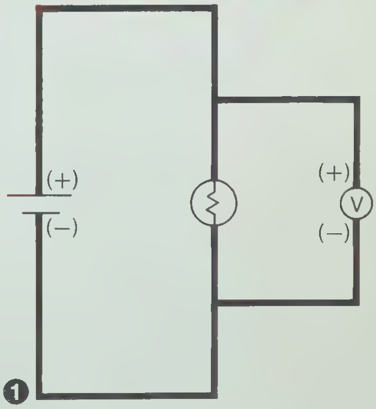
Investigating . . .

Use the voltmeter to find the voltage across one or more bulbs of the *same* size.

1. Pick out three #1 bulbs. Attach your voltmeter in a path with three batteries and *one* bulb.

2. Record the voltmeter reading in Table 6•6 and rate the brightness of the bulb.

3. Add a second bulb to the path. Attach your voltmeter across *both* bulbs. ❷ Record the total voltmeter reading.



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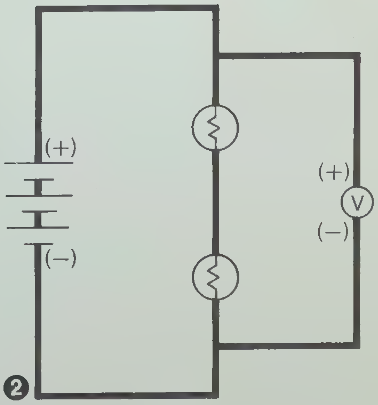
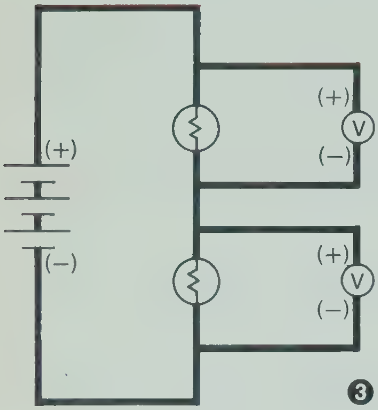


❷

Explain that the diagram shows both places where a voltmeter is to be attached around a bulb. Two voltmeters are not to be attached at the same time.



❸

4. Attach the voltmeter across the *first* bulb only and record the reading. Then attach the voltmeter across the *second* bulb only and record the reading. ❸ Rate the brightness of each bulb.

Add a third bulb to the path. Repeat the activity.

Observing . . .

Table 6·6

Number of bulbs	Total volts	Individual volts			Brightness of bulbs		
		first bulb	second bulb	third bulb	first bulb	second bulb	third bulb
1	Variable. Total	Variable. All individual voltages should be the			Variable. Bulbs should become		
2	voltage should	same, and the sum of the individual voltages should			dimmer as more are added.		
3	remain the same.	equal the total voltage.					

Interpreting . . .

1. Why do you think the total voltage equals the sum of the individual voltages?

Note: Examine your data. Add together the three individual voltages for each bulb as recorded in Table 6·6. Turn to page 241 to find clues for adding and subtracting decimals.

Only one path for the current is available. If one bulb is in the circuit, all the current passes through one bulb. If more than one bulb is in the circuit, the current is split among the bulbs.

Refer students needing help with addition of decimals to the math review activity in the Appendix.

Name ____________________

Date __________ Class __________

2. In which circuit is more voltage used: one containing a single bulb or one containing three bulbs? Give evidence to support your answer.

The same voltage is used in both circuits. The total voltage for a circuit containing 1, 2, or 3 bulbs is the same.

3. Have you observed any relationship between the brightness of each bulb and the voltmeter readings? If so, what is it?

The brighter the bulb, the higher the voltmeter reading.

4. Predict what you think would happen to the voltmeter reading and brightness of the bulbs if the circuit had only one battery. Explain your reasoning.

The voltmeter reading would decrease and the bulbs would become dimmer. Less energy would be available to the bulbs.

Before you continue, read "Bright lights and dim," pages 126–129 in your text.

Again, put bulbs of different voltages in separate containers so students take three *different* size bulbs.

Refer students to Problem B, page 56, for the method of rating the brightness of bulbs.

Refer students needing help with multiplication of decimals to the math review activity in the Appendix.

Check the voltmeter setup of each student.

YOUR TURN: ***How much is a watt?***

A light bulb uses a certain amount of energy per second. The electrical "power" (amount of energy per second) used by a bulb is calculated in *watts*. To calculate watts, multiply the amps times the volts in a circuit.

WATTS = AMPS × VOLTS

Note: Turn to page 241 to find clues for multiplying and dividing decimals.

Set up circuits with 3 batteries and the bulbs listed in Table 6·7. Find the information needed to complete the table.

Table 6·7

Bulb sizes	Amps	Total volts in circuit	Volts around each bulb		Brightness of bulbs	
#1, #2	Variable	Variable. Should be the same throughout.	#1 See note	#2	#1 See note	#2
#2, #3			#2	#3	#2	#3
#1, #3			#1	#3	#1	#3

The sum of the individual voltages should equal the total voltage. But the individual voltage for each bulb should be different. The brightness of the bulbs is variable, but GE 13 should be the brightest and GE 502 the dimmest.

Calculate energy per second in watts used by each *pair* of bulbs. Calculate the energy per second in watts used by each bulb in the circuit.

Before you continue, read "What's a watt?" and "Watts and the electric bill," pages 136–138 in your text.

Name ____________________

Date __________ Class __________

PROBLEM D: ***How much electrical resistance is there in a circuit?***

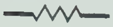
Materials:

1 Voltmeter, 0-8 volts
1 Ammeter, 0-1 amps
2 Batteries, 1.5 volts
3 Resistors, 10, 20, 30 ohms
2 Battery holders
12 Wires with clips

Resistors may be purchased at a radio shop.

Demonstrate how to set up a circuit with a resistor.

To check student results more easily, use the 10-ohm resistor as resistor #1, the 20-ohm resistor as resistor #2, and the 30-ohm resistor as resistor #3.

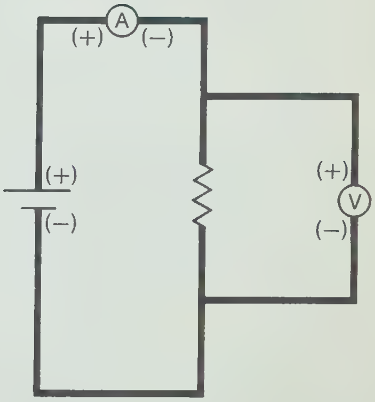
Instead of light bulbs, you are going to experiment with another user of electricity. The user is called a *resistor*. Resistors are shown in a shorthand drawing by  .

Investigating . . .

1. The color bands around the resistors are used for identification. Record the color bands around each resistor (Table 6•8).

2. Now connect the first resistor to a single battery. Place an ammeter in the circuit. Connect the voltmeter across the resistor. Record the amperage and voltage (Table 6•8).

3. Repeat the activity, using two batteries.



Repeat steps 1 through 3 with each of the other resistors.

Observing . . .

Table 6•8

Resistor	Color bands	1 Battery		2 Batteries	
		volts	amps	volts	amps
#1		Variable		Variable	
#2					
#3					

Interpreting . . .

Explain the concept of *resistance*.

Each of your resistors limits the electric current in the circuit. Which one of your resistors allowed the least current? That is, which resistor had the most *resistance?*

Resistor #3.

Resistance is measured in units called *ohms*. One volt divided by one amp equals one ohm:

$$\frac{\text{VOLTS}}{\text{AMPS}} = \text{OHMS (Resistance)}$$

Demonstrate how to calculate *ohms* of resistance. Refer students having trouble with decimals to the math review activity in the Appendix.

1. Use your data from Table 6•8 to calculate the resistance of each resistor (Table 6•9).

Note: Turn to page 241 to find clues for multiplying and dividing decimals.

Student results might vary considerably from the resistor ratings of 10, 20, or 30 ohms. Allow for a large experimental error. It is more important that students see the variation among the three resistors.

Table 6•9

	Resistance	
	1 battery	2 batteries
Resistor #1	Variable	Variable
Resistor #2		
Resistor #3		

You may want to have students calculate the resistance of various household appliances, given the amperage and voltage of such appliances.

2. Which resistor had the least resistance to electric current? Resistor #1 What was its resistance in ohms? 10 ohms

3. What relationship do you see between resistance (ohms) and the current in a circuit (amps)?

The lower the resistance, the greater the current in a circuit.

Name ______________________

Date __________ Class __________

4. Is a light bulb a resistor? Give evidence to support your answer.

   Yes. The bulb limits the current in a circuit. Its resistance can be calculated by finding the voltage across the bulb and the amperage in the circuit.

Before you continue, read "Meeting resistance" and "More resistance," pages 139–141 in your text.

YOUR TURN: ***What is the resistance of a flashlight bulb with two batteries in the circuit?***

Make up your own experiment to find the number of volts a flashlight bulb uses and the amount of current (amps) in the bulb. Then calculate the resistance of the bulb.

Students might also design an experiment to determine the resistance (a) of wires made of various metals and (b) of wires with different diameters.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Connect an electrical circuit by following a shorthand diagram.

2. Draw a diagram of any electrical circuit containing batteries and bulbs or resistors.

3. Use an ammeter to measure the electric current in any combination of bulbs and batteries in circuit.

4. Use a voltmeter to measure the volts used by any combination of bulbs and batteries in a circuit.

5. Find the resistance of a user, in ohms, given the number of volts it uses and the current in amps.

Name ______________________

Date __________ Class __________

BEFORE YOU BEGIN PROBLEM E . . .

Connect two bulbs in a circuit with two batteries. Now try to connect the bulbs so they are both *brighter* than they were before. Then think about this question:

—How many ways can you connect batteries and bulbs in a circuit and what are the results?

PROBLEM E: *When are two electrical paths better than one?*

Materials:

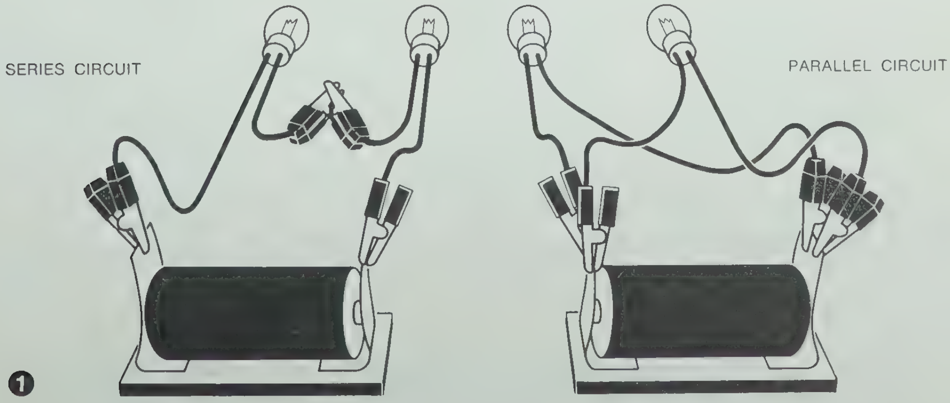
- 1 Battery, 1.5 volts
- 1 Battery holder
- 2 Wired bulb holders
- 2 Bulbs, 3.75 volts
- 1 Voltmeter, 0-8 volts
- 1 Ammeter, 0-1 amp
- 12 Wires with clips

Investigating . . .

A circuit with only one path for the current is a *series* circuit.

Demonstrate how to set up a circuit with bulbs connected in series and in parallel.

A circuit with more than one path for the current is a *parallel* circuit. ①



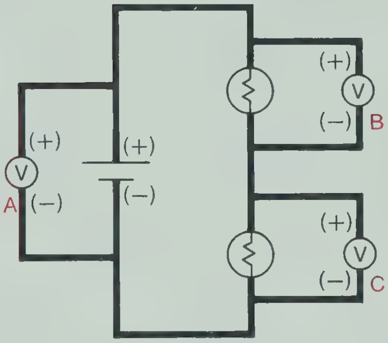
①

1. Connect two bulbs in a series circuit and two bulbs in a parallel circuit. Use only one battery for each circuit. Rate the brightness of the bulbs in each circuit.

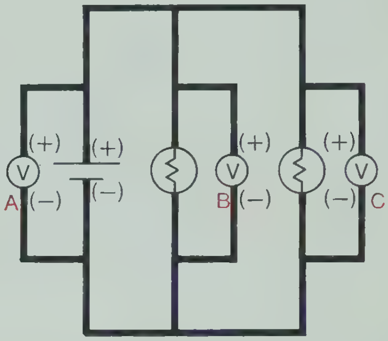
2. Attach a voltmeter at point A in each circuit. ❷ Record the readings in Table 6•10. Then attach the voltmeter at point B in each circuit and at point C in each circuit. Record all the readings.

Check the ammeter and voltmeter setups of each student.

Introduce students to the idea that there can be more than one path for electricity.

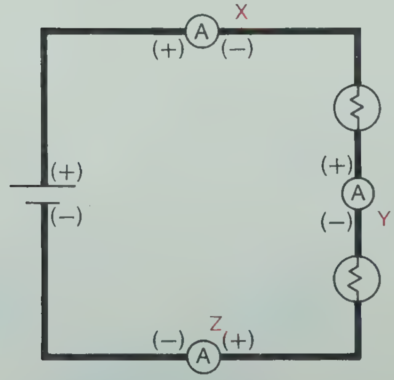


SERIES CIRCUIT

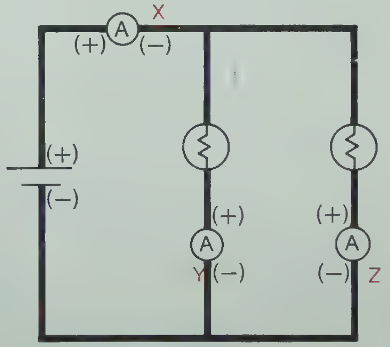


PARALLEL CIRCUIT ❷

3. Attach an ammeter at point X, in each circuit. ❸ Record the readings in Table 6•11. Then attach the ammeter at point X and at point Y in each circuit. Record all readings in Table 6•11.



SERIES CIRCUIT



PARALLEL CIRCUIT ❸

4. Unscrew one bulb in the series circuit and one bulb in the parallel circuit. Record what happens in each case.

Name ____________________

Date __________ Class __________

Observing . . .

A. Table 6·10

Type of circuit	Bulb brightness	Volts at points:		
		A	B	C
Series	Variable. Series bulbs less bright than those in parallel.	Variable. A = B + C		
Parallel		A = B = C		

B. Table 6·11

Type of circuit	Amps at points:		
	X	Y	Z
Series	X = Y = Z		
Parallel	X = Y + Z		

C. What happens when a bulb is unscrewed in a series circuit and in a parallel circuit?

In series, all the bulbs go out. In parallel, the other bulbs remain lighted.

Interpreting . . .

Use Tables 6·10 and 6·11 to answer questions 1 and 2.

1. How does voltage differ in parallel and series circuits?

   In series, the total available voltage is split among the bulbs (users). In parallel, the total voltage is available to each bulb.

2. How does current (amps) differ in parallel and series circuits?

   In series, the current is the same in all parts of the circuit. In parallel, the current can follow more than one path, so it is split among the users.

3. Why are the two bulbs brighter when attached in parallel than when attached in series? Use your observations to support your answer.

   In parallel, about the same voltage is available to each bulb as would be available to a single bulb. In series, only half the voltage is available to each bulb as would be available to a single bulb.

4. Would a parallel or a series circuit be better for a string of burglar alarms? Why? (Hint: look at section C under "Observing . . .")

   A parallel circuit. If one burglar alarm is cut in a parallel circuit, only one circuit path will be broken. The current will go through the other circuit paths to the other alarms.

5. Is your home wired in series or in parallel circuits? Give evidence to support your answer.

   In parallel. As more and more light bulbs are turned on, they do not get dimmer. Each must be on a separate path.

Before you continue, read "Along the electricity circuit" and "Protecting the circuits," pages 142–146 in your text.

Name ____________________

Date __________ Class __________

PROBLEM F: ***When do two batteries make a bulb brighter?***

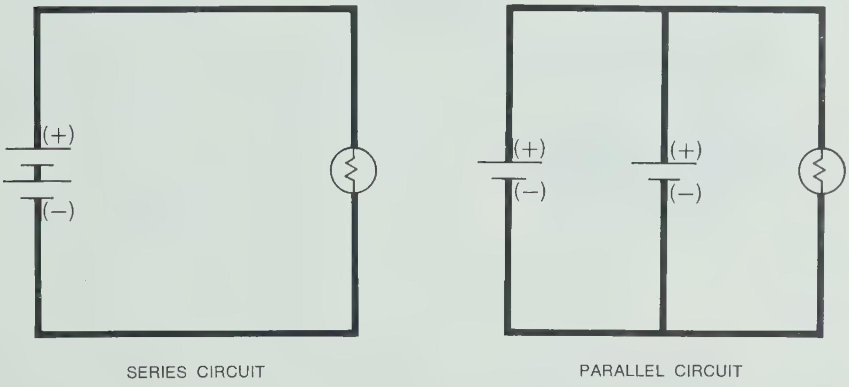
Materials:

- 2 Batteries, 1.5 volts
- 2 Battery holders
- 1 Wired bulb holder
- 1 Bulb, 3.75 volts
- 1 Voltmeter, 0–8 volts
- 1 Ammeter, 0–1 amp
- 12 Wires with clips

Investigating . . .

This time, attach two *batteries* in a series circuit and two batteries in a parallel circuit. Use only one light bulb. Here are the circuit diagrams.

Demonstrate the way to connect batteries in series and in parallel.



Try to find out if there are any differences between batteries connected in series and batteries connected in parallel. Make a hypothesis about differences in bulb brightness and differences in the voltmeter reading for each kind of battery circuit. Carry out an experiment to test your hypothesis.

Observing . . .

Ask students to write a brief description of the procedure they used in their investigation.

Hypothesis:

Variable

Observations:

Variable. Data should include a comparison of bulb brightness for batteries connected in series and in parallel circuits, and amperage and voltage for each type of circuit.

Interpreting . . .

Which type of battery circuit produces a brighter light? Give a possible explanation.

Series circuit. Twice the voltage is available to the bulb in a two-battery series circuit as compared to a bulb in a two-battery parallel circuit.

Now read "Batteries in series and parallel," pages 146–147 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Connect bulbs and batteries in parallel circuits and in series circuits.
2. Describe some differences between the brightness of identical bulbs in parallel and series circuits, given the voltmeter and ammeter readings for each circuit.
3. Make and test a hypothesis about any differences between circuits with batteries in parallel and circuits with batteries in series.

Name ______________________

Date __________ Class __________

CHAPTER 7: ELECTRICITY AND MAGNETISM

BEFORE YOU BEGIN PROBLEM A . . .

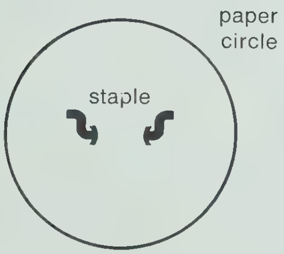
Read "Electricity and Magnetism," page 154 in your text.

Then cut out a small paper circle about the size of a penny. Put a staple through the center of the paper. The staple ends should point out. ❶ Rub the N-pole of a magnet along one end of the staple about thirty times. Always rub from the inside to the outside of the staple. Rub the S-pole of a magnet against the other end of the staple about thirty times.

You will need bar magnets that have their polarity marked. If you do not have them, use a compass to find the polarity of the magnets and mark them before the students use them.

Be sure the students rub the magnet along the staple in only one direction.

Fill a paper cup or small dish with water. Drop the paper circle on top of the water. ❷ Does your staple point in the same direction as the other staples in the classroom? Why? Would the same thing happen to a staple that had not been rubbed with a magnet?



❶

❷

Bring the N-pole and S-pole of a bar magnet near each staple end. What happens? Think about these questions:

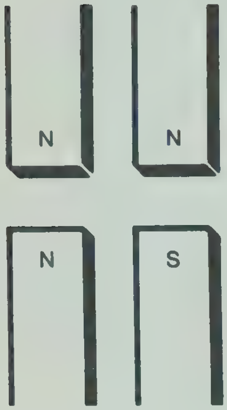
—How does a compass work?

—Is the north pole of a magnet the same as the North Pole of the earth?

—What is a magnetic field?

PROBLEM A: *How do magnets behave?*

Materials: 2 Bar magnets
1 Compass
1 Paper cup (or small dish)
1 Staple (or pin)
Felt-tip pen



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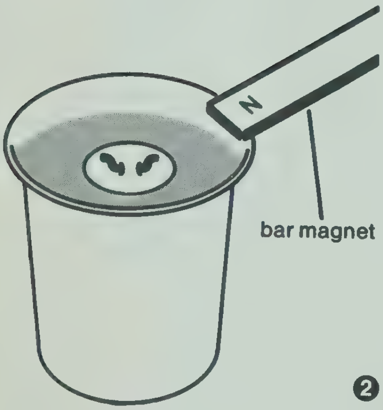


②

Make certain that the students have correctly marked the N-pole of their floating magnets.

I Investigating . . .

1. Bring together the N-poles of two bar magnets. Notice what happens. Do the same thing with the S-poles of your two bar magnets. Finally, bring together the N-poles and S-poles of the magnets. ① Write down what happens in the space provided.

2. Find out if the floating staple you made behaves in the same way as a magnet. Carefully bring the N-pole, S-pole, and then center of your bar magnet near one end of the staple. ② Repeat the procedure, but bring the bar magnet near the other end of the staple. Record your observations.

3. Use your observations to find the N-pole and S-pole of the staple. Mark the N-pole of the staple with a felt-tip pen. Check your observations again to be certain you are right.

Observing . . .

A. Describe what happens when you bring together like poles and unlike poles of two magnets:

Like poles of a magnet repel each other. Unlike poles of a magnet attract each other.

B. Describe your observations of the floating staple and the bar magnet:

One end of the staple is attracted to the N-pole of the magnet and repelled by the S-pole. The other end of the magnet is repelled by the N-pole and attracted by the S-pole.

Name ____________________

Date __________ Class __________

Interpreting . . .

1. What evidence do you have that the floating staple behaves as a magnet?

   Each end of the staple is attracted by one pole of the bar magnet and repelled by the other pole.

2. How did you magnetize the staple? What other kinds of objects do you think you could magnetize?

   One pole was rubbed along each end of the staple a number of times.

   Variable. Any iron or steel object.

II **Investigating . . .**

Slowly move a compass around the edge of your floating staple-magnet. Notice what happens to the compass needle. Record your observations below.

Observing . . .

One end of the compass needle points toward the N-pole of the floating magnet as the compass is moved around that pole. The other end of the compass needle points toward the S-pole of the floating magnet as the compass is moved around that pole.

Interpreting . . .

1. Is the compass needle a magnet? Give evidence to support your answer.

   Yes. Each end of the compass needle is attracted by one pole of the floating magnet and repelled by the other pole.

2. Could your floating staple-magnet be used as a compass? Explain your answer.

   Yes. The magnet is free to turn in any direction. No matter which way the cup is turned, the magnet will turn so that one end points North and the other end points South.

Tying ideas together:

Be certain students understand the difference between geographic north and magnetic north. Have them review their observations for this problem.

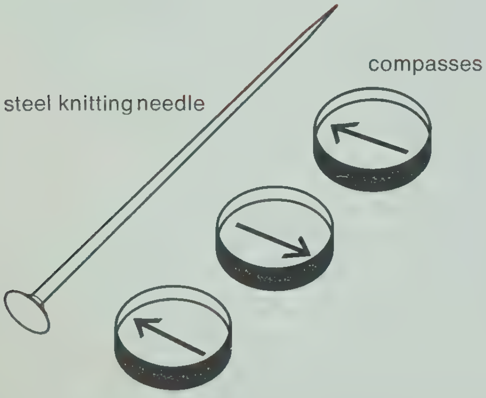
Does your floating-staple magnet point to the north *magnetic* pole of the earth or to the north *geographic* pole? Explain your answer.

North geographic pole. Like poles repel and unlike poles attract. So, the N-pole of the compass needle must point to the south magnetic pole of the earth. However, the N-pole of the compass needle points in a direction called north. This direction is the north geographic pole of the earth.

YOUR TURN: ***Can a magnet have three poles?***

Rub the *same* pole of a bar magnet along *both* ends of the needle, about 50 times.

Try to magnetize a steel knitting needle so the needle has *three* poles. Use a compass to find and to identify each pole.



Name ______________________

Date __________ Class __________

PROBLEM B: *What is a magnetic field?*

Materials: 1 Bar magnet
1 Compass

Investigating . . .

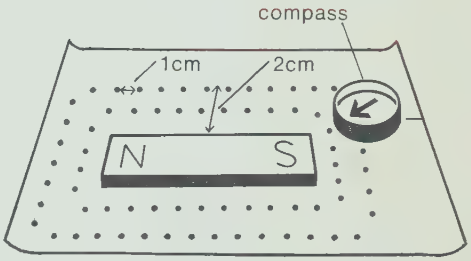
You are going to observe evidence that a magnetic force field exists in the space around a bar magnet.

This experiment works best when a small, inexpensive compass is used.

If your desk is made of steel, put this page on top of a book or a box. Try to figure out why.

The compass needle will be attracted by the bar magnet and the metal surface of the desk. Student observations of the magnetic field around the bar magnet will be affected.

1. Place a bar magnet on the bottom of this page. Trace around the magnet. Mark the N-pole and S-pole of the magnet. Now mark points around the bar that are 1 cm from the bar and 1 cm apart.
2. Mark more points that are 2 cm from the bar and 1 cm apart.
3. Put your compass down on each point. Draw an arrow to show the direction in which the N-pole of the compass is pointing each time.



Observing . . .

Turn to page 156 in the text for a photograph of compasses around a bar magnet.

Interpreting . . .

1. Where are the weakest and strongest parts of your bar magnet? Give evidence to support your answer.

   The strongest parts of the bar magnet are at each end of the magnet. The weakest part is at the center of the magnet. The compass needle is attracted more strongly at the ends, less strongly in the middle.

2. Try to describe the shape of a magnetic field.

   Variable.

3. How would your results be affected if the magnet and compass rested against a metal desk?

   The compass needle would be attracted to both the magnet and the desk. The needle would not point in the same directions as it would if exposed to the bar magnet alone.

YOUR TURN: ***Do all magnetic fields have the same strength?***

If the magnet is placed north-south, instead of east-west, the compass will be affected by the N- and S-magnetic poles of the earth. One pole of the bar magnet will appear to be much stronger than the other pole. For more accurate results, have students place the bar magnet east-west. Also, be sure that they move the compass away from the magnet in an east or west direction only.

Place a bar magnet so it is pointing east and west in the classroom. Put a compass close to the N-pole of the magnet. Slowly move the compass away. When the magnet no longer keeps the compass needle from pointing north, mark that point. Measure and record this distance. Do the same thing at the S-pole of the magnet. The two distances indicate the strength of the magnet's poles (in centimeters).

Try to predict the strength of other bar magnets. Test your predictions.

Before you continue, read "Magnetic fields," pages 155–156 in your text.

Name ____________________

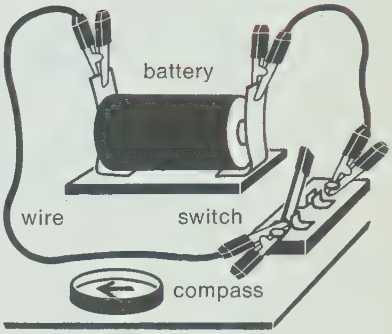
Date __________ Class __________

BEFORE YOU BEGIN PROBLEM C . . .

You are going to make a different kind of circuit and add a new part to this circuit. The new part is called a *knife switch.* If the bar of this switch is up, any circuit you connect with the switch will be open. When you push the bar of the switch down, the circuit will be closed. Remember this as you do the activities that follow.

Warn students that if the batteries are left connected they will run down very quickly.

Now check to make sure the bar of your knife switch is up. Connect your knife switch with a 50-cm piece of covered wire and a battery. Put a compass next to the wire. Does anything happen to the compass needle?



Close the knife switch for about 30 seconds and then open it again. What happened to the compass needle when the switch was closed? Now think about these questions:

—Are electricity and magnetism related?

—How can an electric current produce a magnetic field?

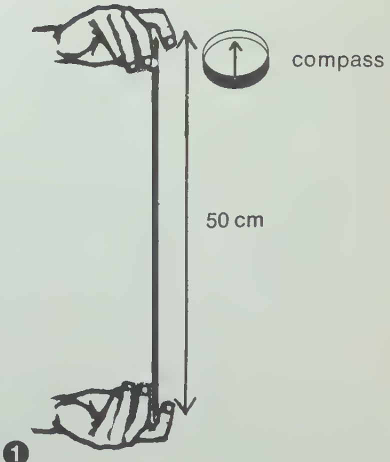
—How can a magnet produce an electric current?

PROBLEM C: *What does an electric current have in common with a magnet?*

Materials:
3 Batteries, 1.5 volts
1 Spool #24 magnet wire, cotton covered
5 Wires with clips
3 Battery holders
1 Compass
1 Knife switch

Investigating . . .

1. Have one classmate hold a 50-cm piece of wire in a straight, up-and-down position. Hold a compass near the *top* of the wire. Notice if the compass needle moves. ❶

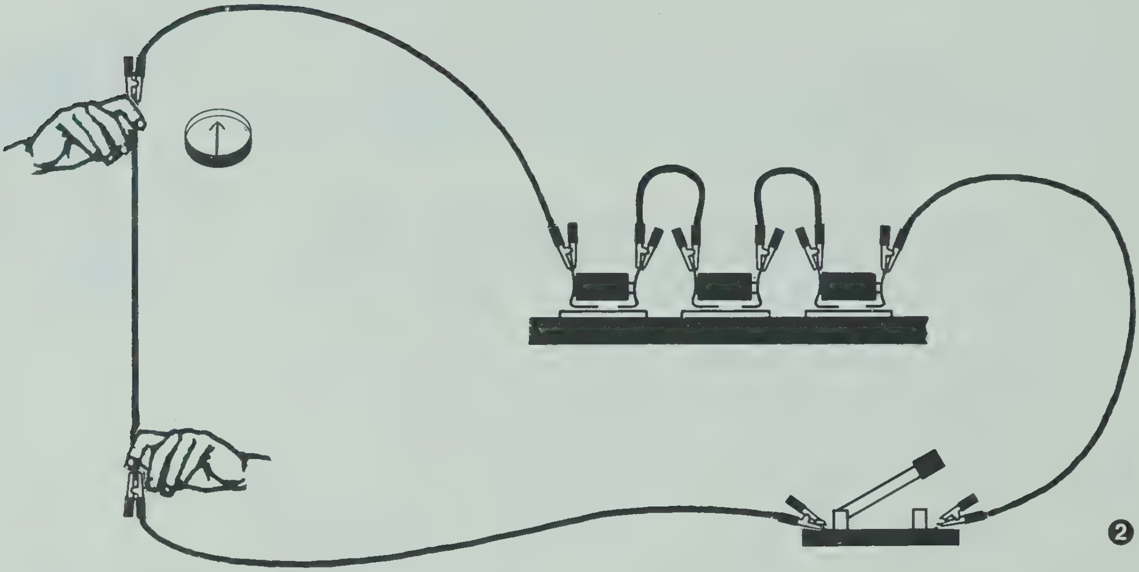


❶

STOP

NEVER leave the knife switch closed for more than a minute. Otherwise, you will ruin the batteries.

2. Connect the wire in a circuit with a knife switch and *three* batteries in series. Close the switch. Notice if the compass needle moves now. ❷



❷

For best results, make certain that the wire is straight. If the ends of the wire are bent toward each other, the results will be affected.

Check to be sure that students have attached the batteries in series.

3. Hold a compass at several spots around the top of the wire. Each circle in the "Observing . . ." section represents a cross section of your wire. Draw arrows around circle A to show the direction in which the N-pole of the compass needle is pointing. Note whether the top of the wire is attached to the (+) or (−) end of the battery.

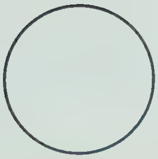
4. Reverse the battery connections. Repeat step 3. Note if the compass needle changes direction. Use circle B for your results.

Name ______________________

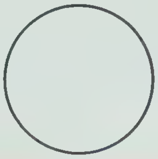
Date __________ Class __________

Observing . . .

A. Top of wire attached to __ terminal



B. Top of wire attached to __ terminal.



Refer to pages 157–159 in the text for photographs of compasses around current-carrying wires.

C. Does the compass needle change direction when the battery connections are reversed?

Yes

Interpreting . . .

1. What effect does an electric current have on a compass needle?

   The current attracts one end of the compass needle and repels the other end.

2. What effect does the *direction* of an electric current have on a compass needle? (Hint: Reversing the battery connections reverses the direction in which current moves through a circuit.)

   As current moves in one direction, one pole of the compass needle is attracted. As the current moves in the opposite direction, the other pole of the compass needle is attracted.

3. What does a wire carrying an electric current have in common with a magnet?

   They both have an N-pole and an S-pole.

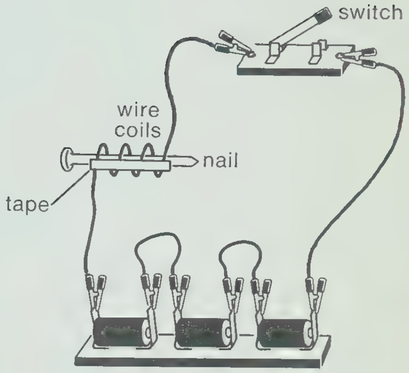
Before you continue, read "Magnets you can turn off," pages 157–159 in your text.

Name ____________________

Date __________ Class __________

PROBLEM D: ***When is a coiled wire a magnet?***

Materials:
1 Spool #24 magnet wire, cotton covered
1 Compass
1 Long iron nail, 20#
3 Batteries, 1.5 volts
3 Battery holders
12 Wires with clips
1 Knife switch
Tape



Investigating . . .

1. Wind 50 loops of wire around an iron nail. Leave about 20 cm of wire at each end of the nail. Tape the coils tightly together.

2. Place the nail and coil under *A.* in the "Observing . . ." section. Connect the coil to an *open* knife switch and three batteries in series.

REMEMBER to close the switch for *less* than a minute at a time. Otherwise, you will ruin the batteries.

3. Hold a compass near different parts of the coil. Close the switch. Note what happens.

4. Trace around the nail and coil. Draw arrows to show the position of the N-pole of the compass needle at positions all around the nail. Mark the north and south poles of the nail.

Reverse the battery connections. This will reverse the direction in which the current moves through the circuit. Move the nail and coil to *B.* in the "Observing . . ." section. Repeat the steps outlined above.

Observing . . .

A. Refer to pages 166 and 167 in the text for photographs of compasses around current-carrying coils.

B.

Interpreting . . .

You just made an *electromagnet.*

1. Name the parts of your electromagnet.

   A nail, wire looped around the nail, batteries.

2. What happens to the nail when current flows through the coil around the nail?

   It becomes a magnet with an N-pole and an S-pole.

3. What happens to the poles of an electromagnet when you reverse the battery connections?

   The poles are reversed.

4. Compare an electromagnet to a bar magnet.

   Variable. Possible answers: A bar magnet always has an N- and an S-pole and always attracts a compass needle. An electromagnet must have current in the coil to have an N- and an S-pole or to attract a compass needle. A bar magnet is made of a piece of iron or steel. An electromagnet is made up of a metal core, wire loops, and a battery.

Before you continue, read "What if you coil the wire?" pages 166 – 167 in your text.

Name ______________________

Date __________ Class __________

PROBLEM E: *What are some things that affect the strength of an electromagnet?*

Materials:

- 6 Long nails, 20#
- 1 Spool #24 magnet wire, cotton covered
- 1 Battery, 6 volts
- 2 Wires with clips
- 1 Ammeter, 0–10 amps
- 1 Compass
- 4 Large paper clips
- 10 Medium paper clips
- Tape

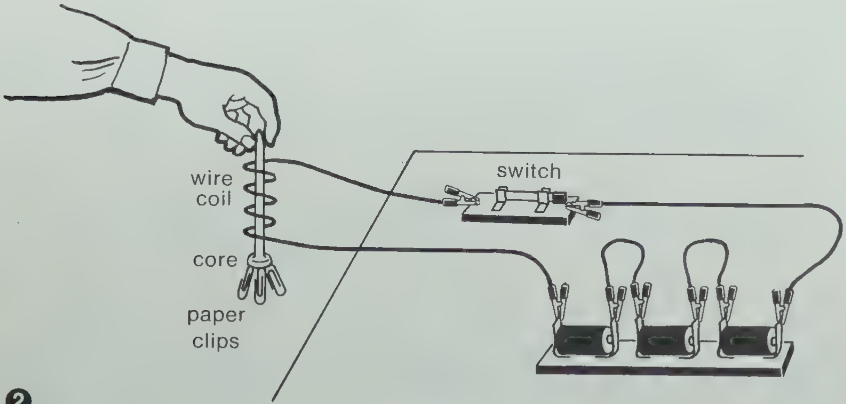
I Investigating . . .

Find out how the size of the metal core affects the strength of an electromagnet.

1. Prepare three electromagnets with 1, 2, and 3 nails in the core. Wrap wire around each core until you have 100 coils. Tape the coils tightly together. ❶

2. Connect the electromagnet with a one-nail core to a 6-volt battery. Use your compass to find the north and south poles of the electromagnet.

3. Now test the strength of the electromagnet. Hold the magnet vertically with the N-pole facing the floor. Add large paper clips, one at a time, until the magnet can hold no more. Then add the smaller paper clips. ❷ Record the number of clips attracted by the N-pole of the electromagnet (Table 7·1). Record the strength of the south pole in the same way.



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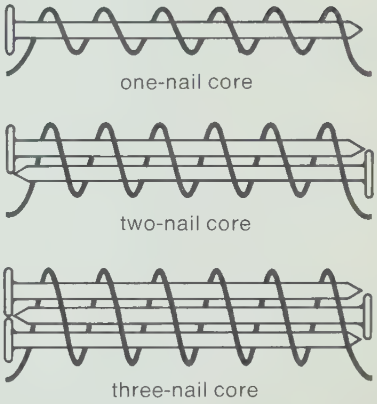


❶

Illustration number 1 shows how the nails are arranged in the cores of the electromagnets. Notice that the coils are wound so that they do not overlap. To fit 100 coils of wire around each core, the students will have to wind the wire very tightly. Each coil will touch the coils on either side of it. The coils must be taped in place so they do not slip off the core after the electromagnet is wound. A finished electromagnet should look like the ones shown on page 169 of the text.

Repeat the steps to find the strength of the electromagnet with a two-nail core and of the electromagnet with a three-nail core.

Observing . . .

Table 7·1

Size of core	Magnet strength (number of paper clips)	
	north pole	south pole
1 nail	Both poles should be approximately the same strength. Some variation will occur, depending on the direction in which students hold their electromagnets.	
2 nails		
3 nails	As the size of the core increases, the strength of the electromagnet should increase.	

Interpreting . . .

What effect does the size of the core have on the strength of an electromagnet?

The larger the core, the greater the strength of the electromagnet.

II **Investigating . . .**

Now find out how the number of coils around the core affects the strength of an electromagnet.

1. Attach an electromagnet with a three-nail core to a 6-volt battery. Use paper clips to find the strength of the N-pole or S-pole. Record the strength (Table 7·2).

2. Unwind 10 coils of wire. Find the strength of the N-pole or S-pole again. Record your results.

Continue to unwind 10 coils of wire at a time, until 70 coils are left. Test the strength of the magnet each time. Record your results in Table 7·2.

Name ______________________

Date __________ Class __________

Observing . . .

Table 7·2

Number of coils	Magnet strength (number of paper clips)
100	The strength of the electromagnet decreases as the number of coils decreases.
90	
80	
70	

Interpreting . . .

What effect does the number of coils have on the strength of an electromagnet?

The greater the number of coils, the greater the strength of an electromagnet.

Tying ideas together:

Describe two ways to increase the strength of an electromagnet.

(a) Increase the size of the iron core. (b) Increase the number of wire coils.

Before you continue, read "The strength of electromagnets," pages 168–169 in your text.

Name ______________________

Date __________ Class __________

PROBLEM F: ***How can a magnet produce an electric current?***

Materials:
1 Cardboard tube, 4-cm diameter
1 Spool #24 magnet wire, cotton covered
1 Bar magnet
1 Milliammeter, 0–100 milliamps
Tape

You can substitute the simple compass galvanoscope for a milliammeter in this activity. Instructions for making the galvanoscope are in the "On Your Own" on page 165 of the text. A sensitive galvanometer will also work here if one is available.

This activity may be used as a teacher demonstration.

Investigating . . .

1. Wind wire around a tube of cardboard until you have 50 coils. Hold the coils together with tape.

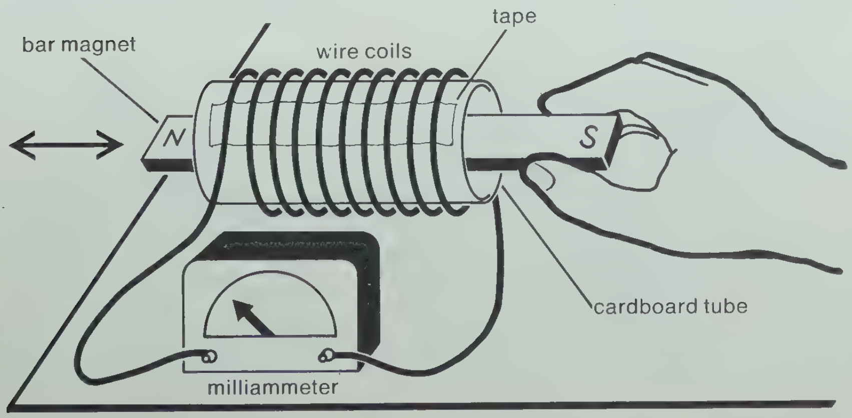
2. Connect the wire coil to a *milliammeter*. A milliammeter measures very tiny amounts of electric current—less than 0.001 amps.

3. Slowly push the N-pole of a bar magnet into the coil. Note if the milliammeter needle moves. Slowly pull the bar magnet out of the core. Observe what happens to the milliammeter needle. Try several more times. Record your observations in Table 7•3.

4. Repeat step 3 with the S-pole of the bar magnet. Record your observations.

Repeat the experiment. This time, push the magnet into the coil rapidly and pull it out rapidly several times. Record your observations.

5. Let the bar magnet sit in the coil. Note if the milliammeter needle is affected.



Observing . . .

Table 7·3

Magnet pole	Speed within coil	Movement of milliammeter needle
N	Slow	Probably less than 5 milliamps when pulled out of coil.
S	Slow	Probably less than 5 milliamps when pushed into coil.
N	Rapid	Probably around 5 milliamps when magnet pulled out of coil.
S	Rapid	Probably around 5 milliamps when magnet pushed into coil.
—	None	Does not move.

Interpreting . . .

Try to explain your observations of the milliammeter needle as recorded in Table 7·3.

A small electric current is produced when a magnet is either pushed into or pulled out of a coil. The more rapidly the magnet is pushed in and out, the greater is the current. When there is no motion between the magnet and the coil, no current is produced.

Now read "Reversing the process," pages 170–171 in your text.

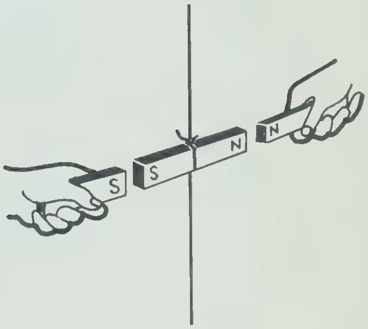
SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Map the magnetic field around a bar magnet.
2. Build an electromagnet, given wire, a metal core, and batteries.
3. Map the magnetic field around an electromagnet.
4. Predict the effect on the strength of an electromagnet, given a change in the current through the coils, in the number of coils, or in the size of the core.
5. Use a magnet to produce an electric current in a wire coil.

Name ____________________

Date __________ Class __________

CHAPTER 8: THE WHIRRING OF MOTORS



BEFORE YOU BEGIN PROBLEM A . . .

Read "The Whirring of Motors," page 188 in your text.

Then suspend a bar magnet between two pieces of string. Pull the free end of each piece of string tight. Have another classmate hold two bar magnets on either side of the suspended magnet. Make the suspended magnet revolve. Now think about these questions:

—How does an electric motor work?

—What is an electric generator?

PROBLEM A: *How does an electric motor work?*

Materials:
2 Round bar magnets
1 Block of wood, 12 × 20 × 1 cm
1 Pencil (without eraser)
1 Roll bell wire, 20 gauge
1 Battery, 6 volts
2 Large paper clips
2 Flat corner irons (5/8 × 4 in)
6 Thumbtacks
2 Wires with clips
Tape

The bell wire and flat corner irons can be purchased at a hardware store. The bell wire should be used as it is purchased from the hardware store.

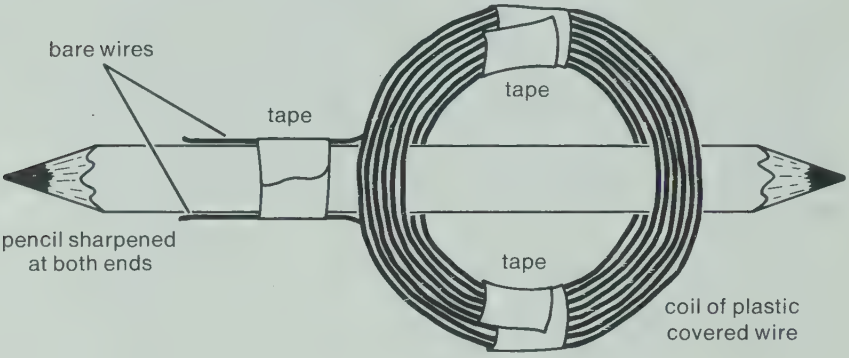
Investigating . . .

Use what you know about electricity and magnetism to build an electric motor.

1. Begin by sharpening a new pencil at both ends. Then push the pencil through a roll of bell wire. Fasten the coils of wire in place with several pieces of masking tape.

Step 1 is illustrated on the next page.

2. Pull out about 2 cm of wire at each end of the roll, and peel off the plastic coating. Attach the bare wires to one end of the pencil. Keep the wires on opposite sides of the pencil. ❶

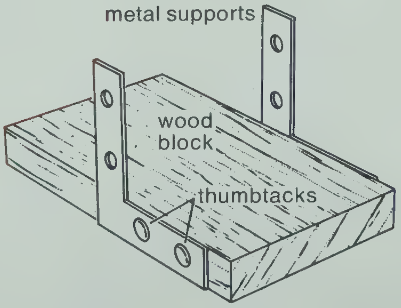


❶

3. Make a frame for your motor by attaching two metal supports to each side of a wooden block. You can attach the metal supports with thumbtacks. ❷ Suspend the pencil and coil between the metal supports of the frame. This coil will carry the current. In a motor, the coil is called an *armature*.

Have students rub the pencil point along the inside of the two holes in the frame that support the pencil. The graphite will act as a lubricant. In addition, if the pencil is supported by the exposed graphite, the armature will turn more easily.

4. Straighten out two paper clips as shown. ❸



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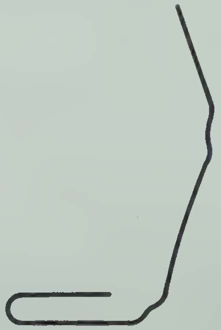


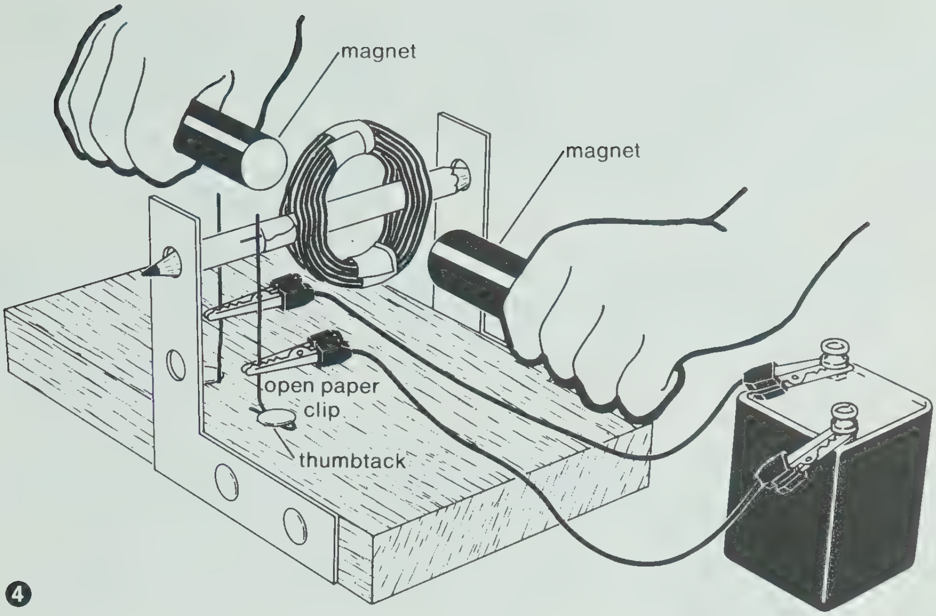
❸

5. Tack the paper clips to the board, one on either side of the pencil. The clips should make firm contact with the exposed wires of the coil. The contact wires (paper clips in this case) are called *brushes*.

6. Attach a 6-volt battery to the brushes as shown. Hold two round bar magnets so the unlike poles face each other. Hold one magnet on either side of the coil—as close as you can get without touching the coil. ❹

Name ____________________

Date __________ Class __________



❹

Now, start your motor by spinning the armature and holding the magnets in place. If the motor doesn't revolve, check these things:

—Is the armature balanced evenly on the pencil?

—Are the brushes making firm contact with the wires?

—Are the exposed wires far enough apart?

—Is the battery fresh?

—Are the magnets in the right position? (Try holding one magnet higher than the other. Try turning the magnets around.)

—Is the pencil turning freely?

Once your motor starts spinning, try moving the magnets closer to the armature, then farther away. Observe what happens.

Put a compass down on one side of the armature. Remove the magnets and turn the armature by hand. Notice what happens to the needle of the compass as the armature turns.

The motors may need some minor adjustments, so go over the checkpoints with the students.

Have one student spin the armature while another student holds the magnets in different positions.

If "pulsations" can be felt in both magnets, as the armature is turned, then the motor is operating properly. However, it may take several attempts before the right magnet position is found and the motor begins spinning "on its own."

If the motor still doesn't spin, have a third student hold a pair of magnets parallel to the pair held by the second student. It may take four magnets to spin the motor if the magnets are not strong enough.

Observing . . .

A. Describe how well your motor is working. For example, how rapidly is the armature turning, how smoothly?

Variable.

B. Describe how the distance of the magnets from the armature affects the motor.

As the magnets are moved away, the motor slows down and finally stops.

C. As the armature is turned, what happens to its magnetic poles?

The poles reverse.

Interpreting . . .

1. Is the armature of your motor an electromagnet? Give evidence to support your answer.

   Yes. The movement of the compass needle indicates that the armature has an N-pole and an S-pole.

2. How can you change the poles of an electromagnet?

   Change the direction of the electric current.

3. Would an iron core make your motor more powerful? Give evidence to support your answer.

   Yes, it would make the motor more powerful. The strength of an electromagnet can be increased by increasing the size of the core. Therefore, adding any iron core should also increase its strength.

4. How does the distance of the magnets from the armature affect the speed of the motor? Explain your answer.

   When the magnets are closer to the armature, the magnetic field affecting the armature is stronger. The stronger the magnetic field, the more rapidly the armature will spin.

Before you continue, read "Electromagnetism put to use" and "Keep it turning," pages 189–192 in your text.

Name ____________________

Date __________ Class __________

PROBLEM B: *What affects the energy per second used by a motor?*

Materials:

- 1 Small electric motor
- 3 Batteries, 1.5 volts
- 3 Battery holders
- 12 Wires with clips
- 1 Ammeter, 0–1 amp
- 1 Voltmeter, 0–8 volts

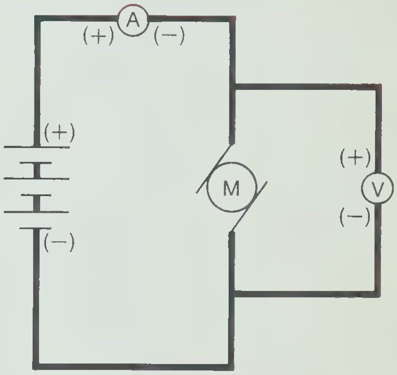
Investigating . . .

1. First, locate the armature, brushes, and magnets on your ready-made motor. Then attach the motor to one flashlight battery. Connect an ammeter in the circuit. Also connect a voltmeter around the motor. Record the amperage and voltage in Table 8•1.

2. Attach a second battery to the circuit in series. Record the readings in the same table. Add a third battery, in series, and again record the readings.

3. In each case, calculate the energy per second or the power in *watts* used by the motor. Remember, to calculate wattage multiply the amperage times the voltage. (Amps × Volts = Watts)

Help students locate the armature, brushes, and magnets of the motor.



Have students notice the symbol for an electric motor.

Note: Turn to page 241 to find clues for multiplying and dividing decimals.

Observing . . .

Table 8•1

Number of batteries	Amps	×	Volts	=	Watts
1		×		=	
2		×		=	
3		×		=	

Variable.

Wattage increases as the batteries are increased.

When the number of batteries is increased, more power is available to the motor. When the field magnets and/or the armature are strengthened, the magnetic field inside the motor is strengthened.

Interpreting . . .

Describe some ways the number of watts used by a motor could be increased. Use your observations in Problems A and B.

Possible answers: (a) Increase the number of batteries. (b) Increase the strength of the magnets. (c) Increase the size of the core. (d) Increase the number of loops around the armature.

Before you continue, read "What if you had a horse," page 193 in your text.

Name ____________________

Date __________ Class __________

PROBLEM C: ***How can you generate electricity?***

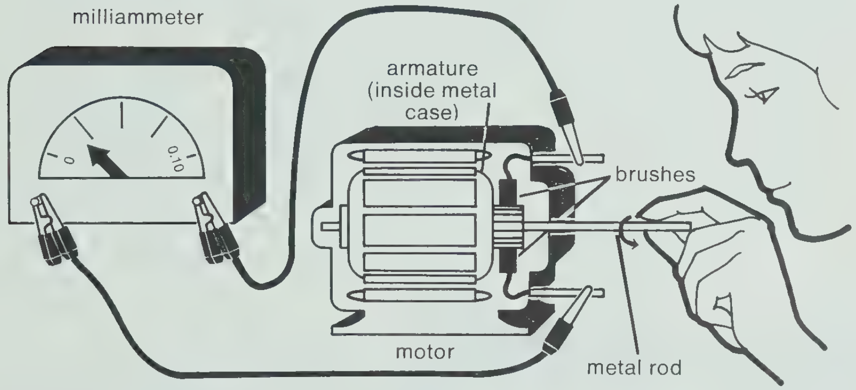
Materials:

- 2 Small electric motors
- 1 Ammeter, 0–10 amps
- 1 Milliammeter, 0–100 milliamps
- 3 Batteries, 1.5 volts
- 3 Battery holders
- 6 Wires with clips
- Tape

A delicate galvanometer can be used in place of a milliammeter. If no other equipment is available, a simple compass galvanoscope can be used to prove current is generated. However, this instrument is not quantitative.

I Investigating . . .

1. Connect the wires of a motor to a milliammeter. Use your hand to spin the metal rod coming out of the armature. Record any milliammeter readings in Table 8·2.



2. Notice if the direction in which you spin the armature changes the reading. Observe if the speed at which you spin the rod changes the reading.

Observing . . .

Table 8·2: One motor

Direction of rotation	Speed of rotation	Milliammeter reading
Left	Slow	Variable. In one direction no ammeter reading, in the other direction an ammeter reading. Increases as the speed of rotation is increased.
	Fast	
Right	Slow	
	Fast	

An ammeter measures current in only one direction. Current moving in the other direction does not register, and it would break the ammeter if it were a strong current. However, the current in this experiment is quite weak.

Interpreting . . .

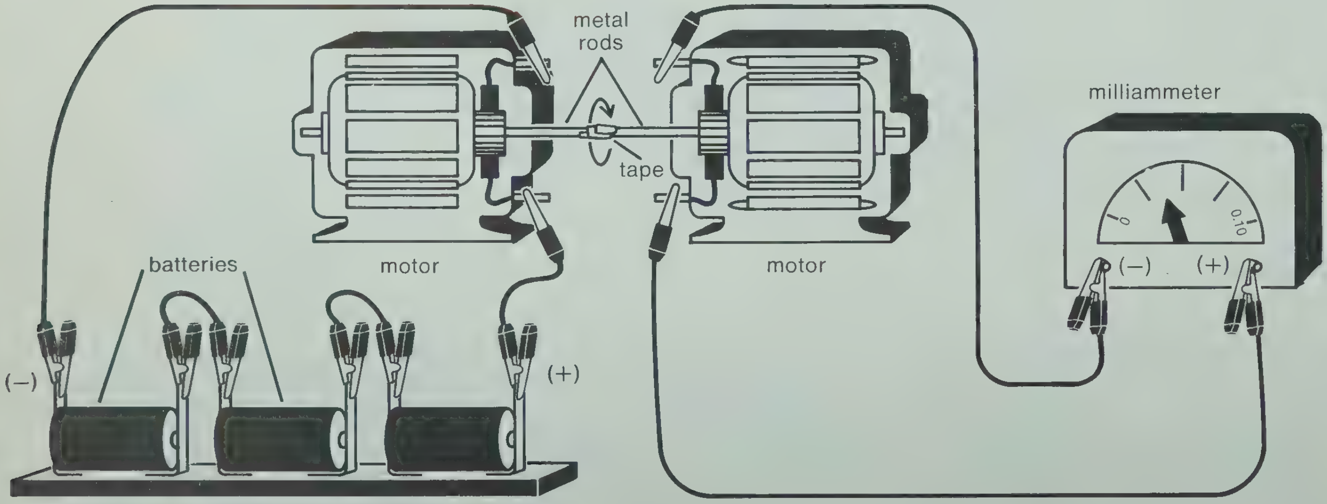
How is the speed at which the rod turns related to the ammeter reading?

As the speed at which the rod turns increases, the ammeter reading increases.

II **Investigating . . .**

Check student setups to be certain the milliammeter is attached to the correct motor.

1. Now tape together the metal rods of two motors. Both rods should turn together easily. Attach one of the motors in a series circuit with three batteries. Connect a milliammeter to the other motor. Record the milliammeter reading in Table 8•3.



2. Remove one battery. Record the milliammeter reading again. Remove a second battery. Again record the milliammeter reading.

Name ____________________

Date __________ Class __________

Observing . . .

Table 8·3: Two motors

Number of batteries	Milliammeter reading
1	Variable.
2	Increases as the number of batteries is increased.
3	

Interpreting . . .

1. In the setup with two motors, the motors are not on the same electrical circuit. The battery provides the power for the motor on its circuit. What causes the motion of the motor on the circuit without the battery?

   The motion of the first motor.

2. In this experiment, is an electric current being *generated?* How do you know?

   Yes. There is a small ammeter reading, indicating that there is an electric current in the circuits that are not attached to a battery.

3. What two energy sources did you use to generate electricity?

   (a) Energy from the movement of hands and arms.
   (b) Energy from the movement of the battery-operated motor.

Ask students what other energy sources could be used to generate electricity.

4. Which of your two energy sources generated more current? Give evidence to support your answer.

   The battery-operated motor. The milliammeter reading was higher when the battery operated motor was used to generate electricity.

To increase the electrical output of your generator (a) increase speed of armature, (b) increase strength of magnets, (c) increase the number of coils, (d) increase the size of the core, (e) increase the number of batteries.

YOUR TURN: ***How could you increase the electrical output of a generator?***

Predict how each of the following could be changed to improve the electrical output of your generator: (a) speed of armature, (b) strength of field magnets, (c) number of coils, (d) core, (e) energy source. Find a way to test one of your predictions.

Now read "Generating electricity," pages 194–195 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Build an electric motor, given the parts of a motor.
2. Demonstrate how a simple motor operates.
3. Measure the amount of electrical energy per second used by a small electric motor.
4. Change a small electric motor to an electric generator.
5. Measure the current produced by a small electric generator.

Name ____________________

Date __________ Class __________

CHAPTER 9: THINGS IN MOTION

Many of the activities in this unit involve averaging data from three or more trials. Students should be aware that results obtained in a trial may be "off." Explain to students that such results should be dropped before averaging and results from a new trial substituted if time permits.

BEFORE YOU BEGIN PROBLEM A . . .

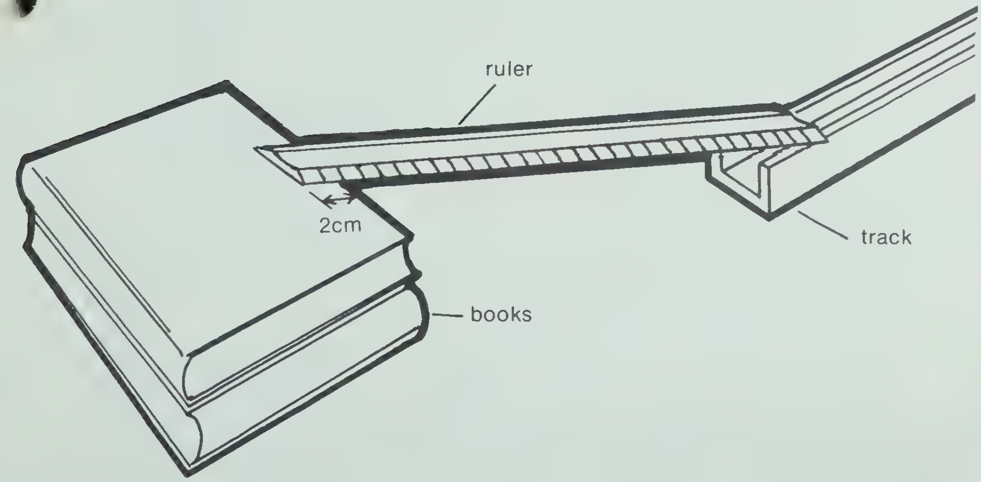
Read "Motion" and "Things in Motion," pages 216–220 in your text.

Then set up your track as shown in the drawing.

Place some marbles on the track. Roll some other marbles down the ruler so they run into the marbles you put on the track. Notice what happens to the marbles on the track. Now think about these questions:

—How would you find the speed of an object, say a marble or a grocery cart?

—Is it harder to stop a cart full of groceries or an empty cart when both are moving at the same speed?



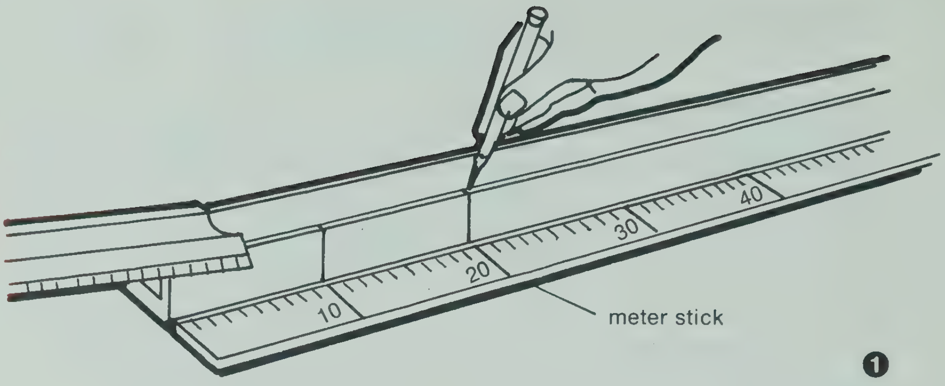
PROBLEM A: *How do you find the speed of an object?*

Materials:
- 1 Marble
- 1 Metal track
- 1 Stopwatch
- 1 Plastic ruler with groove down center
- Pencil
- Ruler
- Books

The track is an aluminum shelving support, about 2 m (6 ft) long. It can be bought at a hardware store.

Have students work in pairs if possible, threes at most.

Glass marbles are to be used in Problem A. The marbles move down the track so rapidly that stopwatches must be used to time them. If necessary, borrow stopwatches from the PE department. Demonstrate the operation of the stopwatches being used. Check to see that students are operating and reading the stopwatches properly.



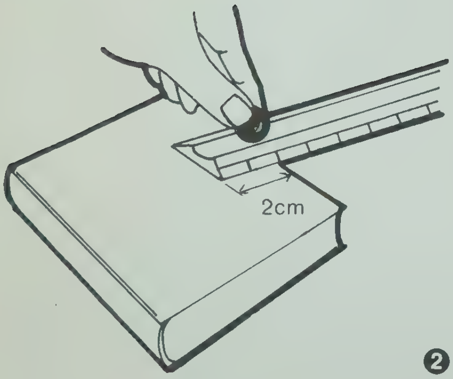
❶

Investigating . . .

1. Make a pencil mark every 10 cm along the length of your track. ❶ Then use one book to set up the track. The edge of the ruler should be about 2 cm from the edge of the book.

2. Start from the *edge* of your book and let a marble roll down the ruler. ❷

3. Have one member of your lab group time the rolling marble as follows: Start a stopwatch when the marble touches the first mark on the track. ❸ Stop it when the marble touches the last mark on the track. Record the stopwatch reading in Table 9·1. Time three more trials with the rolling marble. Record your times.



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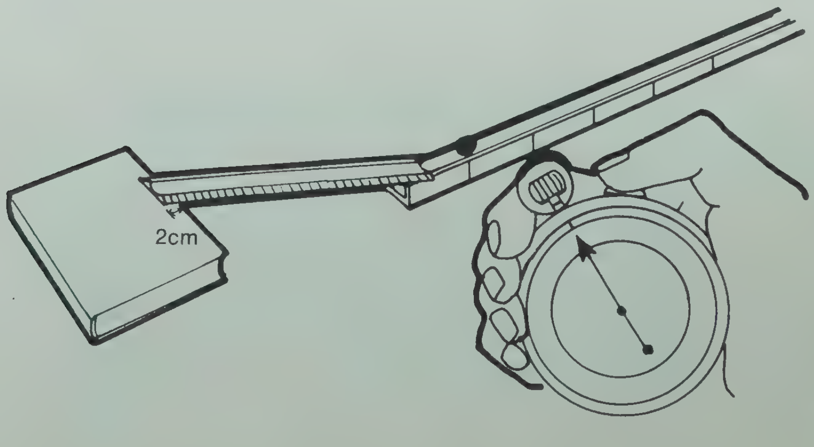

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Name ____________________

Date __________ Class __________

4. Add all your stopwatch readings. Then divide the total by 4 to get the *average* time the marble took to move the length of the track. Record the average time in Table 9•1.

Discuss averaging. Show students how to drop any results that are "way out" before averaging.

Repeat the activity three more times. Change the height of the track by adding another book to the stack each time. During each trial, keep the edge of the ruler about 2 cm from the edge of the books.

Observing . . .

Table 9•1

Run	Height of books above track, cm	Distance between first and last marks, cm	Time for marble to travel between first and last marks on track, seconds					
			trial				total	average
			1	2	3	4		
1	About 1.6 (1 book)	Varies with length of track	Varies according to the length of the track					
2	About 4.5 (2 books)							
3	About 7.4 (3 books)							
4	About 9.3 (4 books)							

Interpreting . . .

Average speed is defined as the distance an object travels divided by the time it takes the object to travel that distance.

$$\text{AVERAGE SPEED} = \frac{\text{DISTANCE}}{\text{TIME}}$$

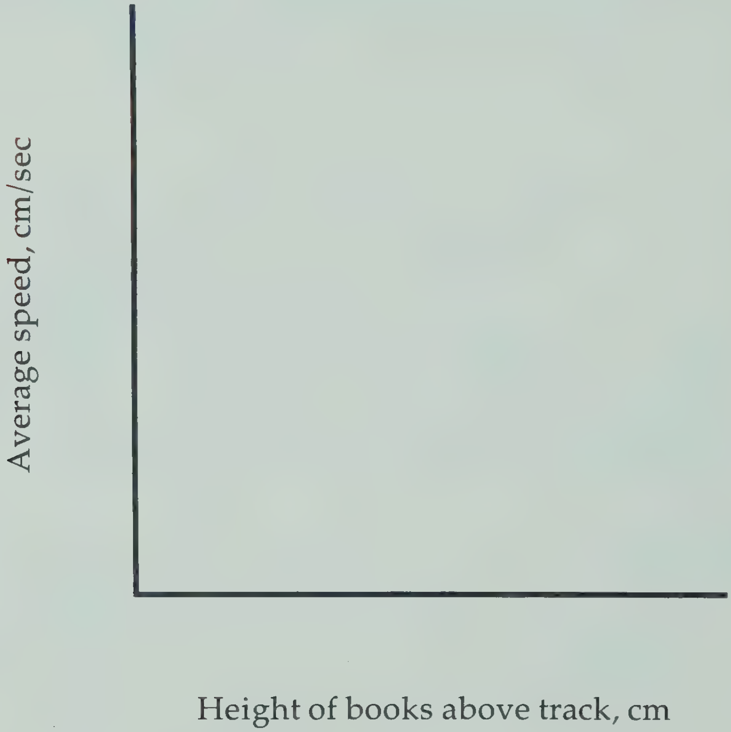
1. What was the marble's average speed during each of the four runs? (Give your answer in *cm per sec.*)

Run	1	2	3	4
Average speed, cm/sec	Variable. It should equal distance divided by average time.			

2. Make a line graph of the average speed of the marble versus the height of the books above the track for each run.

Refer students having trouble with graphing to page 247 in the Appendix.

Note: Turn to page 247 to find clues for making line graphs.



3. Is the height of the books related to the average speed of the marble? Use your graph and Table 9·1 to support your answer.

Yes. When the marble is let go from the top of a high stack of books, it travels down the track faster. The marbles traveled at the greatest average speed when they were let go from the top of the stack of 4 books.

Before you continue, read "Whoosh and thud" and "How fast the whoosh?" pages 221 – 224 in your text.

Name ______________________

Date __________ Class __________

PROBLEM B: ***Why are some marbles harder to stop than others when they are all moving at the same speed?***

Materials:

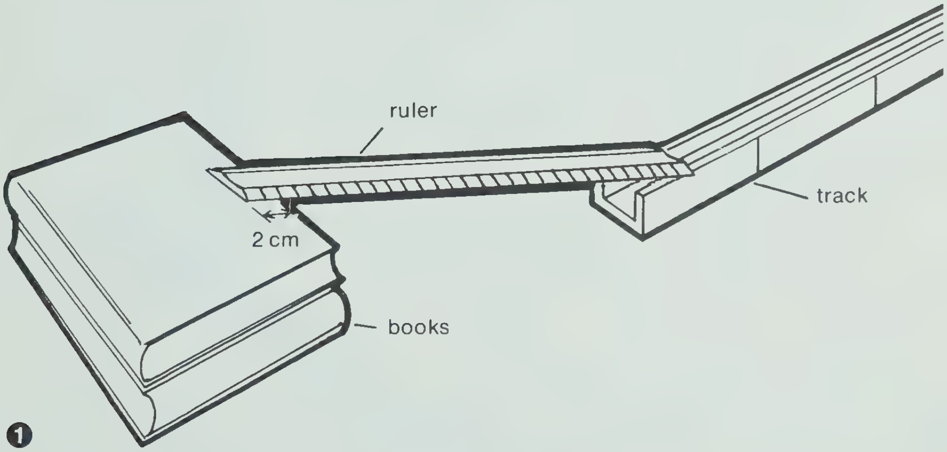
- 4 Marbles of different types
- 1 Metal track
- 1 Equal-arm balance
- 1 Set of standard masses
- 1 Stopwatch
- 1 Plastic ruler with groove down center
- Books
- Ring stand and ring
- Paper clip
- Metal washers
- String

Marbles should be as close as possible to the same size. To get marbles with different masses, try plastic, ordinary glass, and various ball bearings.

I Investigating . . .

1. Set up a track as you did in Problem A, page 104. Use two books under the track. ❶

This activity works best with 2-student lab groups.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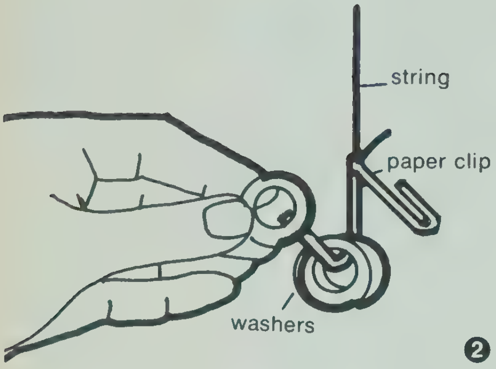
2. Now take four different kinds of marbles. Describe the color of each marble or the kind of material each marble is made of (Table 9•2).

3. Start the first marble down the ruler at the point where your ruler crosses the edge of the books. Measure the time it takes the marble to move from the first mark on the track to the last mark. Record the time in Table 9•2.

4. Find the average speed of the marble. Record the average speed in Table 9•2.

Repeat the activity to find the speed of each of your other marbles.



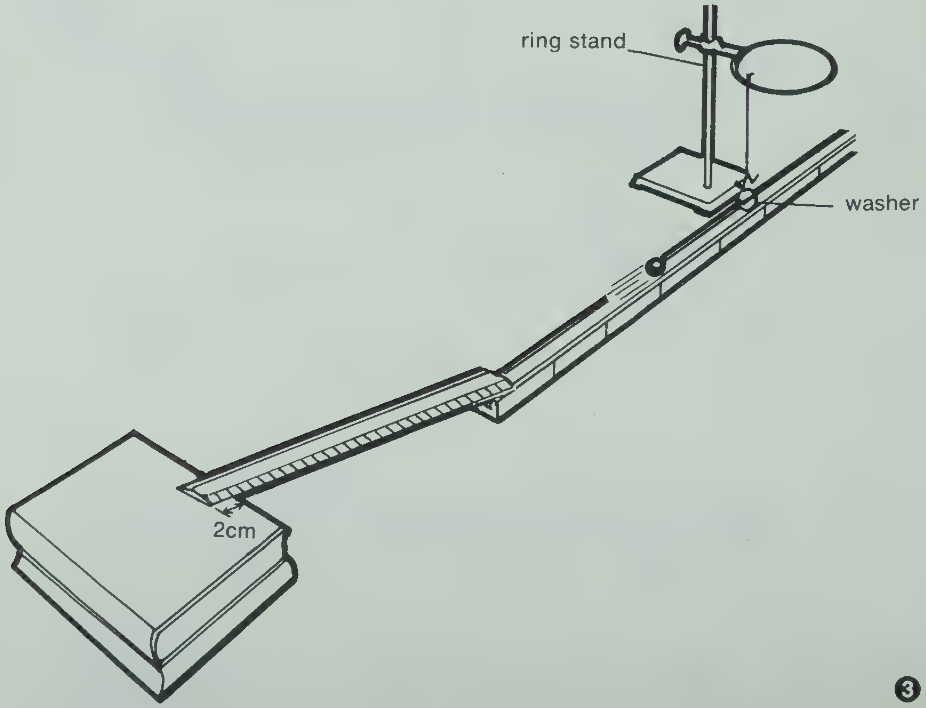
❷

5. Next, tie an opened paper clip to a piece of string. Attach the string to a ring stand. Place the ring stand next to the track.

6. Hook a washer on the paper clip. ❷ Be sure the washer is almost touching the track and is at right angles to the track.

7. Now let your first marble roll down the track into the washer. ❸ Add washers to the paper clip until the washers stop the marble. Record the number of washers it takes to stop this marble, in Table 9•2.

Find out how many washers it takes to stop each of the other marbles. Record what you find.



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Name ____________________

Date __________ Class __________

Observing . . .

Table 9·2

Marble	Description	Distance, cm	Time, sec	Average speed, cm/sec	Number of washers to stop marble
#1	Should include color of marble or material it is made of			Same for all	Variable
#2					
#3					
#4					

Interpreting . . .

1. How does the average speed of all four marbles compare?

   It is the same. They all roll from the same height.

2. Why do you think it takes more washers to stop some of the marbles?

   Variable. Might include: They are made of different materials. They are heavier than others. They have greater mass.

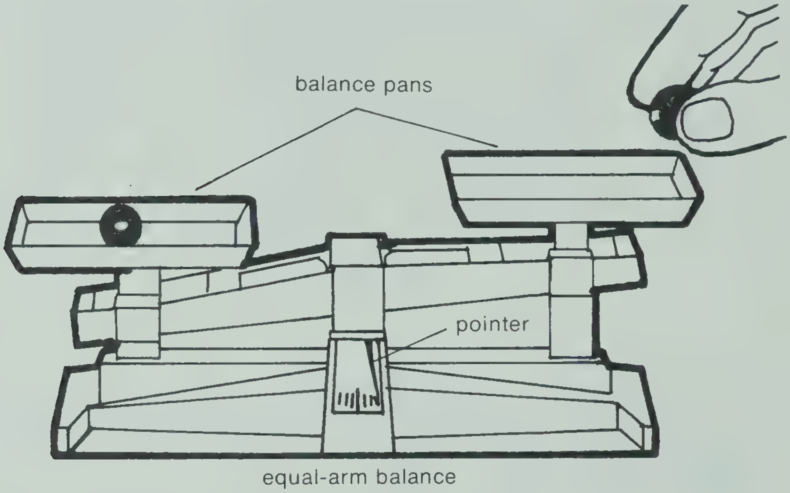
II Investigating . . .

1. Hold the marble that was easiest to stop in your left hand. Hold the marble that was hardest to stop in your right hand. Record any difference you notice between the marbles in Table 9·3.

   Switch hands and again record any noticeable difference.

2. Put the marble that was easiest to stop on the left pan of an *equal-arm balance.* Put the marble that was hardest to stop on the right pan. Record what happens to the balance pans in Table 9·4.

   Replace the "hardest-to-stop" marble with each of the other marbles. Record what happens.



Observing . . .

A. Table 9·3

Marble in left hand	Marble in right hand	Observation
Easiest to stop	Hardest to stop	Marble in right hand seems heavier.
Hardest to stop	Easiest to stop	Marble in left hand seems heavier.

B. Table 9·4

Marble on left pan	Marble on right pan	Observation
Easiest to stop	Hardest to stop	Pan with "harder-to-stop" marble goes down. Pan with "easiest-to-stop" marble goes up. Pointer goes toward pan with "easiest-to-stop" marble.
Easiest to stop	Variable	
Easiest to stop	Variable	

Name ____________________

Date __________ Class __________

Interpreting . . .

1. Which marble was hardest to stop?

   The marble that feels "heaviest."

2. Which marble pushed the balance pan farther down?

   The marble that feels "heaviest" or the marble that was hardest to stop.

3. Which exerted the most strain on your hand when you held it?

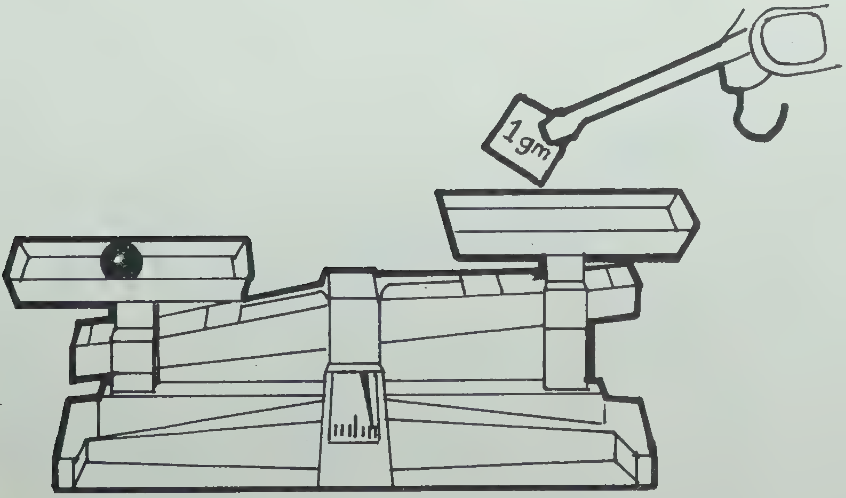
   The marble that was hardest to stop.

III **Investigating . . .**

The property that determines which marble is hardest to stop when both are traveling at the same speed is called *mass*. Mass is also the property that determines which marble pushes down harder on a balance pan. Mass can be measured with an equal-arm balance and a set of standard masses.

Discuss difference between mass and weight.

1. Here's the way to find the mass of your marbles: Put a marble in one of the balance pans. Put a 1-gm mass in the other pan. Continue to add or remove masses until the arm of the balance stays level. Add up all the masses in the pan. This number is the mass of the marble in the other pan.



Note: Turn to page 253 to find more clues for using an equal-arm balance to measure mass.

Refer students having trouble using equal-arm balance to page 253 in the Appendix.

2. Use your equal-arm balance and standard masses to find the mass of each marble. Record the masses in Table 9•5.

Observing . . .

Table 9•5

Marble	Mass, grams
#1	Variable
#2	
#3	
#4	

Interpreting . . .

1. Which marble has the most mass?

   Variable

2. How did the marble that was hardest to stop compare with the marble that pushed the balance pan farther down?

   It was the same marble.

Tying ideas together:

1. If a truck and a car hit a wall at the same speed, which would do the most damage? Explain your answer. (Hint: Use your observations from Table 9•2 and Table 9•5.)

   The truck. It has a greater mass and is harder to stop.

Before you continue, read "How great the thud?" and "What is mass and what isn't it?" pages 225–231 in your text.

Name ____________________

Date __________ Class __________

PROBLEM C: ***How do speed and mass of a moving object affect its motion?***

Materials: Same as for Problem B, page 107.

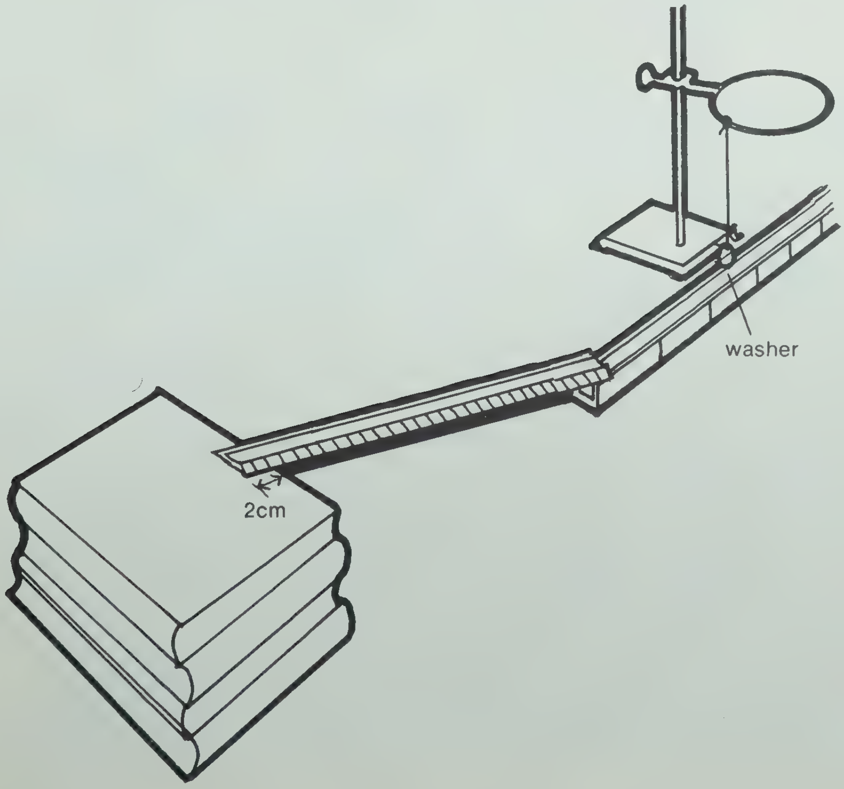
Investigating . . .

Use 2-student lab groups if possible.

1. Set up your track as you did in Problem A, page 104. This time use four books. Place the grooved ruler so a marble will roll down the ruler onto the track.

2. Use the marble with the greatest mass and the one with the least mass (see Table 9•5, page 112). Start each marble where the ruler crosses the edge of the books. Let each marble roll down the track. Find the average speed of each marble. Record the average speed in Table 9•6.

3. Now arrange the ring stand next to the track as you did in Problem B, page 108. Put enough washers on the paper clip to stop the marble with the greatest mass. See Table 9•2, page 109, to find how many washers you used.



4. Let the marble roll down the ruler from the edge of the top book. Notice whether or not the marble stops.

5. If the marble doesn't stop, find how many washers you need to stop it. Record the number of washers in Table 9·6.

Repeat the procedure with the other marble.

Add two more books to your stack. Reset the grooved ruler so the marble still rolls down onto the track. Find the speed of each marble and the number of washers it takes to stop each marble, just as you did above. Record this information in the same table.

Observing . . .

A. Does the marble with the least mass stop when it strikes the same number of washers used in Table 9·2? No

Does the marble with the greatest mass stop when it strikes the same number of washers used in Table 9·2? No

B. Table 9·6

Number of books	Marble	Mass, gm	Speed, cm/sec	Number of washers needed to stop marble
2	Least mass			Variable.
2	Greatest mass			
4	Least mass			Greater than in Table 9·2.
4	Greatest mass			
6	Least mass			Increases as speed increases.
6	Greatest mass			

Name ____________________

Date __________ Class __________

Interpreting . . .

1. When you increased the speed of each marble, did you need more or fewer washers to stop the marbles? Explain your answer.

   More washers were needed to stop the marbles. When a marble goes faster it "pushes" harder.

2. Is it harder to stop your bike when you are riding fast? Or is it harder to stop your bike when you are going slowly?

   It is harder to stop when you are riding fast.

Tying ideas together:

1a) When a marble rolls into the washers, the washers are *pushed* forward by the marble. You have found two ways to increase this push. What are they?

a) Use a marble with a larger mass. b) Increase the speed of the marble.

b) Do you think your answer is true for objects other than marbles? Give examples from your everyday life that support your answer.

Yes. Examples will vary. They could include the fact that less damage is done in auto accidents at low speed; baseballs are more likely to break windows than tennis balls, etc.

2. One of the qualities of the marble's motion that involves its speed and its mass is called *momentum*. One way of calculating momentum is:

Discuss momentum.

(SPEED OF MARBLE) × (MASS OF MARBLE) = MOMENTUM

Calculate the momentum of the marbles you used. Take your data from Table 9·2, page 109 and Table 9·5, page 112 to fill in Table 9·7a.

Table 9·7a: Momentum of marbles

Marble	Mass, gm	×	Speed, cm/sec	=	Momentum, gm·cm/sec
#1	Variable				
#2					
#3					
#4					

Take your data from Table 9·6, page 114 to fill in Table 9·7b.

Table 9·7b

Marble	Number of books (height)	Mass, gm	×	Speed, cm/sec	=	Momentum, gm·cm/sec
Least mass	2	Variable				
Greatest mass	2					
Least mass	4					
Greatest mass	4					
Least mass	6					
Greatest mass	6					

3. Do you see a relationship between the momentum of a marble and the number of washers needed to stop it? If so, what is the relationship?

   Yes. The greater the momentum of a marble, the more washers it takes to stop it.

4. If you increase the speed of a marble while its mass remains the same, what happens to its momentum?

   It increases.

Name ______________________

Date __________ Class __________

PROBLEM D: ***What happens to momentum in a collision?***

Again use 2-student lab groups—4 students per group at most.

Materials:

- 1 Metal track
- 1 Equal-arm balance
- 1 Set of standard masses
- 8 Marbles of same size and mass
- 1 Ruler with groove
- 1 Stopwatch
- Books

Marbles of the same size and very close to the same mass should be in a large container in front of the class.

Investigating . . .

1. Set up the track as you did in Problem A, page 104.

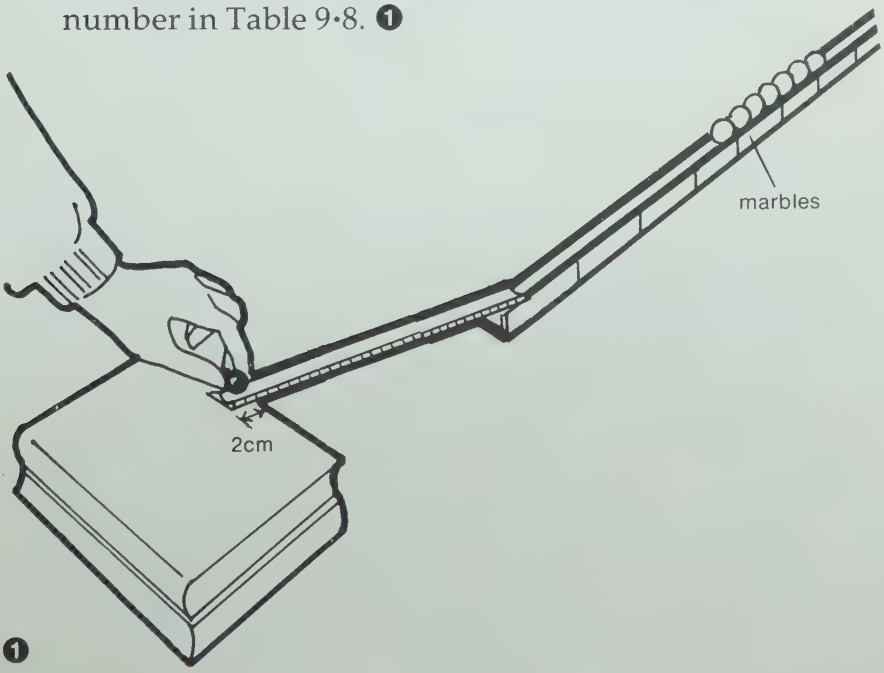
2. Use eight marbles that are the same size and mass. Find the mass of one marble and record it in Table 9•8.

3. Let one marble roll down the ruler from the edge of the books and along the track. Find and record the average speed of the marble. (Any marble rolled from that height will travel along the track at the same speed.)

4. Put the rest of your marbles in a row in the center of the track. Make sure all the marbles are touching.

5. Let one marble roll from the edge of the books into the row of marbles. Notice how many marbles leave the row when hit by the first marble. Record this number in Table 9•8. ❶

The row of marbles should be in the center of the track. The whole row of marbles might spin in place when hit. But only as many marbles as hit the row will roll down the track away from the row.



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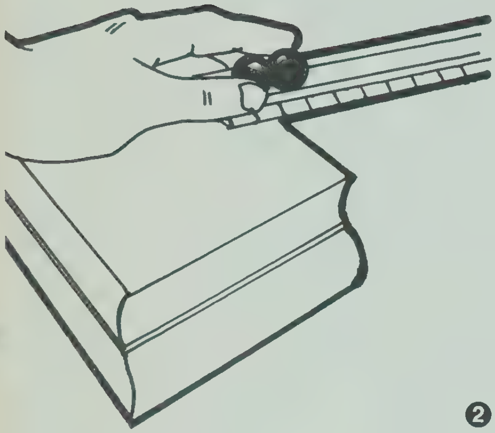
Run two more trials with the same marble. Each time, be sure all the marbles in the row are touching. Record your results.



6. Take another marble from the row on the track. Now roll two marbles into the row at the same time. Record what happens in Table 9·8. ❷

Run two more trials using two marbles.

Observing . . .

The speed of the marble(s) on the track is ____ cm/sec.

❷

Table 9·8

Trial	Marbles hitting row		Marbles leaving row	
	number	mass, gm	number	mass, gm
1	1 small	Variable	Number and mass should be same as that of marbles hitting row.	
2	1 small			
3	1 small			
4	2 small			
5	2 small			
6	2 small			

Interpreting . . .

1. Is the mass of the marble(s) hitting the row about equal to the mass of the marble(s) leaving the row in each instance?

   Yes. The same number of marbles that hit the row, leave the row. And all the marbles have about the same mass.

Name ______________________

Date __________ Class __________

2. Remember, all the marbles that roll down from the same height travel down the track at the same average speed. Assume that the marble(s) leaving the row is traveling at the same speed as the marble(s) which hits the row. (They would do so in an ideal situation.)

   Now use Table 9·9 to calculate the momentum of the marble(s) hitting the row and of the marble(s) leaving the row.

Table 9·9

Marbles hitting row					Marbles leaving row				
mass, gm	×	speed, cm/sec	=	momentum, gm·cm/sec	mass, gm	×	speed, cm/sec	=	momentum, gm·cm/sec
Should be the same on both sides									

3. When two objects roll into each other, is momentum the same before and after the collision? Use your data to explain your answer.

   Yes. In Table 9·9, momentum is the same before and after the collision.

YOUR TURN: ***Can you make the momentum of the "lightest" marble equal to the momentum of the "heaviest" marble?***

Make up your own experiment. Try to give the same momentum to marbles of different masses.

Now read "Bumping into things," pages 246–251 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Find the average speed of an object.
2. Find the momentum of an object.
3. Explain how momentum is affected by speed and mass.
4. Perform an experiment to show what happens to momentum in a collision.

Name ____________________

Date __________ Class __________

CHAPTER 10: USING FORCE

BEFORE YOU BEGIN PROBLEM A . . .

Read "Using Force," page 253 in your text.

This chapter is about the push or pull that changes an object's motion. The name for that push or pull is *force.*

Lift (pull) your book off the table. Put it down and push it across the table. Do the same thing with several other things. Now think about these questions:

—How can you measure the amount of push or pull needed to change an object's motion?

—What happens to the speed of a wagon full of newspapers if you keep pulling it with the same force?

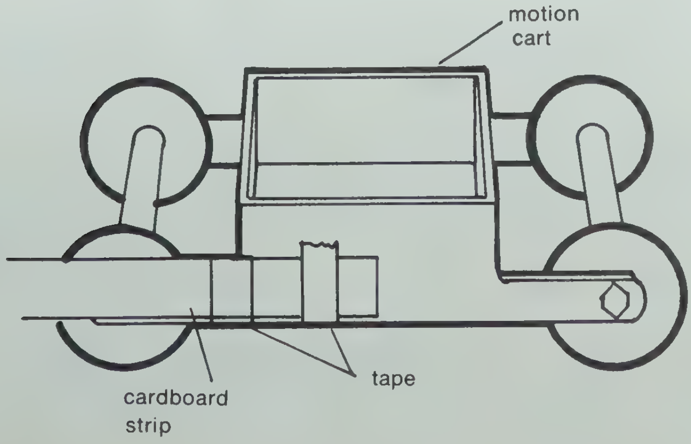
PROBLEM A: *What happens when you apply constant force to a motion cart?*

Materials:		
	1 Kilogram mass	1 Motion cart
	1 Rubber band	1 Stopwatch
	Cardboard cutout M, page 263	3 Meter sticks

Investigating . . .

Each group of four students should prepare one cart as follows:

1. Cut out the cardboard strip marked M on page 263. Tape it to the side of your motion cart. ❶ It should stick out in front of the cart.



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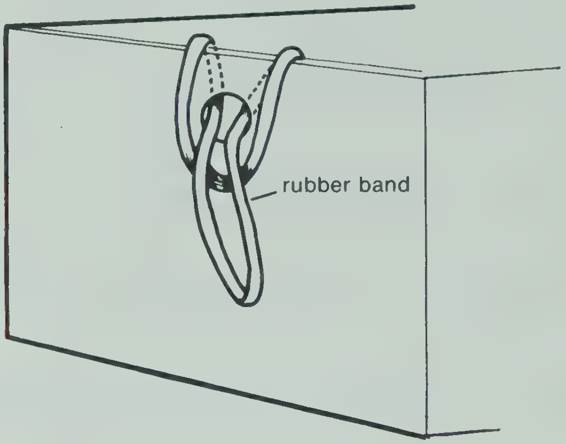
Since this activity is rather complicated, it might be advisable for students to try several practice runs before recording any data.

Suggested lab team size—four students.

This experiment can be done in the corridor, if there is not enough space in the classroom.

Use #18 rubber bands. These are 7.6 cm x 2 mm x 1 mm (3″ x 1/16″ x 1/32″).

2. Attach a rubber band to the cart as shown. ❷



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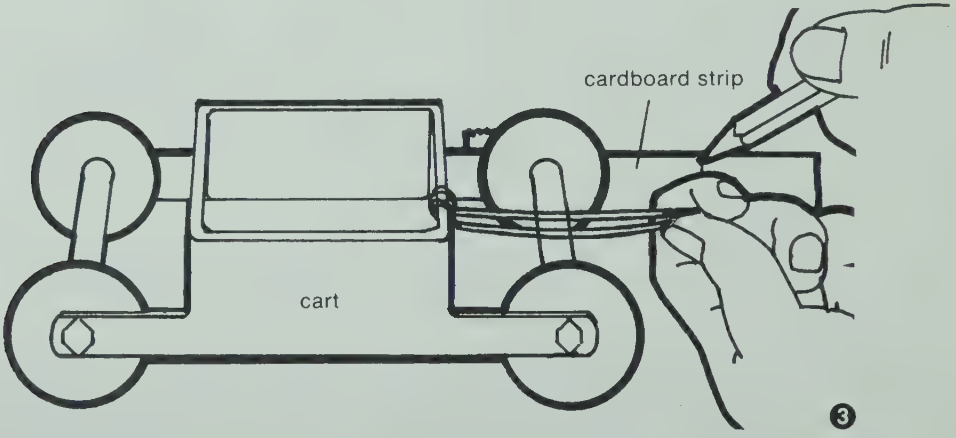
3. Hold the rubber band straight out in front of the cart without stretching it. Mark the length of the rubber band on the cardboard strip. Put two more marks on the strip, 1 cm and 2 cm from the first one. ❸



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4. Lay three meter sticks end to end on the floor. Put a 1-kg mass in the motion cart. Then put the cart next to the meter sticks. The front of the cart should be in a line with the front end of the meter sticks.

Four people are needed to do this experiment. Each person should follow one set of directions.

Person #1.

Pull the cart 3 m with the rubber band. Keep the end of the rubber band at the first mark on the strip. You are pulling the cart with a constant force of 1 mark.

Name ______________________

Date __________ Class __________

Person #2.

Use a stopwatch to find how long it takes the cart to travel 3 m. Record the time in Table 10·1.

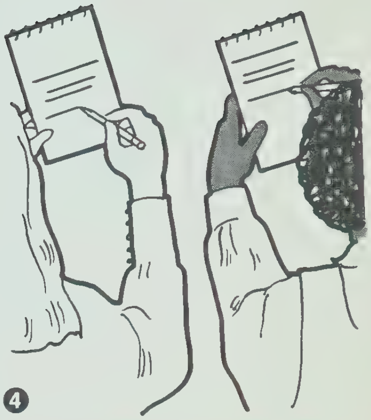
Person #3.

Hold a pencil and a pad of paper. Practice drawing a line at the same speed as person #4. You *must* each draw a line at the same speed if this experiment is to work. ④

Stand 150 cm from the starting point. Start drawing a line when the cart gets to the 1-meter mark. Stop drawing the line when the cart gets to the 2-meter mark. Call the line, *line 1-2*. Measure the length of the line and record it (Table 10·1).

Person #4.

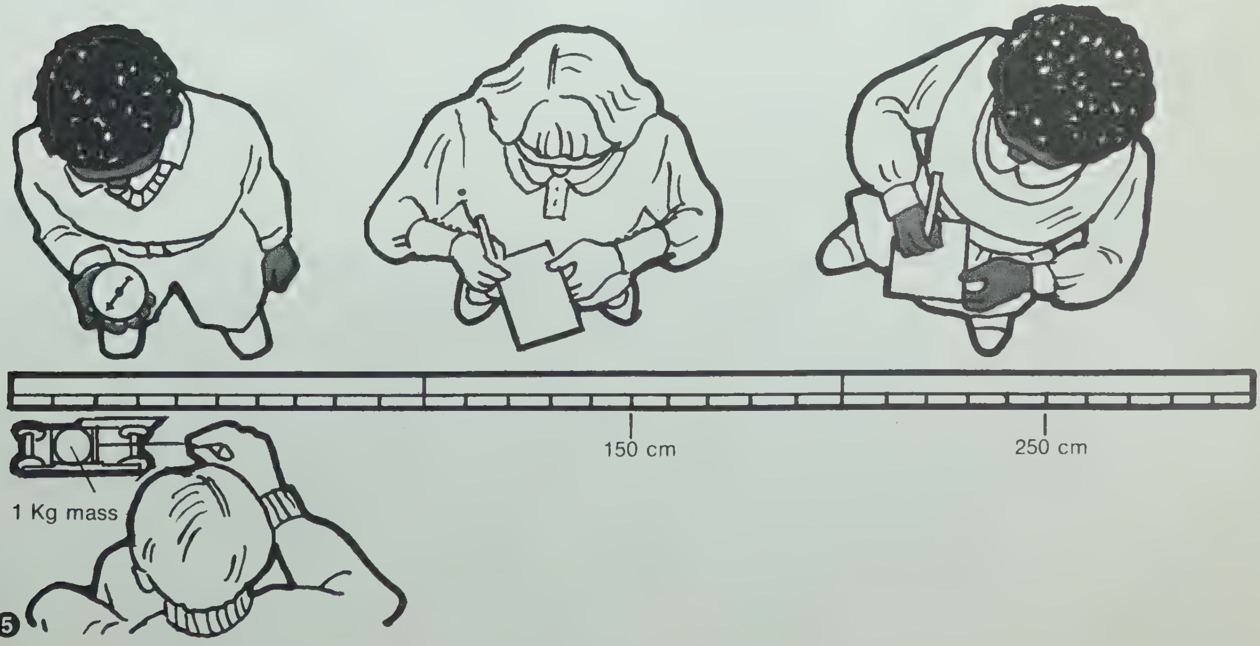
Hold a pencil and a pad of paper. And practice drawing a line at the same speed as person #3. Then stand 250 cm from the starting point. Start drawing your line when the cart gets to the 2-meter mark. Stop when the cart gets to the 3-meter mark. Call your line, *line 2-3*. Measure the length of your line and record it (Table 10·1). ⑤



④

The students who will draw lines must practice drawing them at the same rate. This is a rough way of showing acceleration. But it does work. Some of the chance for error can be avoided by having the students who draw lines change places at each trial.

The cart moves very rapidly during this experiment. Students cannot use a stopwatch to accurately measure how long it takes the accelerating cart to travel 1 m.



⑤

Entire group.

Repeat the activity two more times. Record the length of the lines and the time it took the cart to travel 3 m (Table 10•1).

Repeat the activity again, but use *two other* constant forces. Pull the cart with the rubber band at the second mark (force of 2 marks). Record your measurements in Table 10•2. Then pull the cart with the rubber band at the third mark (force of 3 marks). Record your measurements in Table 10•3. Be careful not to fall down as you pull the cart with greater force.

Observing . . .

Table 10•1: Cart pulled with force of 1 mark

Trial	Time, sec	Length of line 1-2, mm	Length of line 2-3, mm
1		Line 1-2 should be longer than line 2-3.	
2			
3			
Total			

$\frac{\text{Total time}}{\text{3 trials}}$ = average time:

Name ______________________

Date __________ Class __________

Table 10·2: Cart pulled with force of 2 marks

Trial	Time, sec	Length of line 1-2, mm	Length of line 2-3, mm
1		Line 1-2 should be longer than line 2-3.	
2			
3			
Total			

$\frac{\text{Total time}}{\text{3 trials}}$ = average time:

Table 10·3: Cart pulled with force of 3 marks

Trial	Time, sec	Length of line 1-2, mm	Length of line 2-3, mm
1		Line 1-2 should be longer than line 2-3.	
2			
3			
Total			

$\frac{\text{Total time}}{\text{3 trials}}$ = average time:

Interpreting . . .

1. How is the average time it takes for the cart to go 3 m affected as you increase the constant force on the cart from 1 mark to 3 marks?

   It takes less time as the force increases.

2. Does the cart travel the entire 3 m at the same speed? (Hint: Was there any change in the sound the cart made as it rolled along? Is line 1-2 always the same size as line 2-3?)

   No.

   Person #3 and person #4 tried to draw lines at the same speed. Thus the lines are crude clocks. The longer the line, the longer it took the person to draw it. The longer the line, the longer it took the cart to travel the meter the line represents.

3. What happens to the speed of the cart as you pull it 3 m with a constant force of 1 mark? or 2 marks? or 3 marks?

   The "harder" the cart is pulled, the quicker the speed of the cart increases.

Before you continue, read "Pushing a car" and "Using a truck in place of muscles," pages 254–257 in your text.

YOUR TURN: ***Is the weight of a loaded motion cart equal to the force needed to pull it across 3 meters?***

Force is not usually measured by the stretch of a rubber band. It is measured by the stretch of a spring. A pointer attached to the spring moves up and down the scale as the spring stretches and contracts.

Design an experiment that will provide data comparing the weight of the motion cart with the force needed to pull it on a flat surface. Use a motion cart, a 1-kilogram mass, and a *spring force measurer.*

Before you continue, read "Force and weight," pages 257–259 in your text.

Name ____________________

Date __________ Class __________

PROBLEM B: ***What happens when you apply a constant force to a motion cart without wheels?***

Have students work in pairs. They can take turns pulling the cart and measuring the rubber band or reading the force measurer.

For more information on the spring force measurer, refer students to the "Your Turn" on page 126.

Demonstrate how to read the scale on the force measurer in newtons.

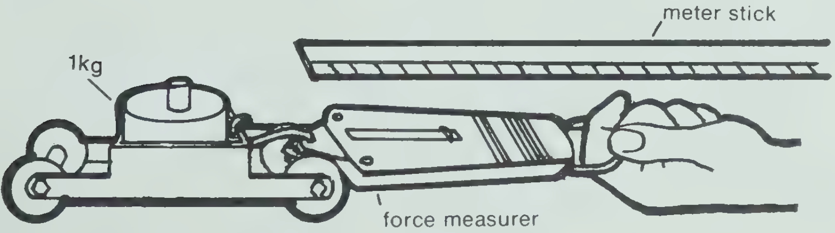
Materials:
1 Meter stick
1 Kilogram mass
1 Spring force measurer, 0–20 N
Motion car used in Problem A, page 121

Investigating . . .

1. Place the meter stick across the top of your lab table. Put the motion cart containing a 1-kg mass at one end of the meter stick.

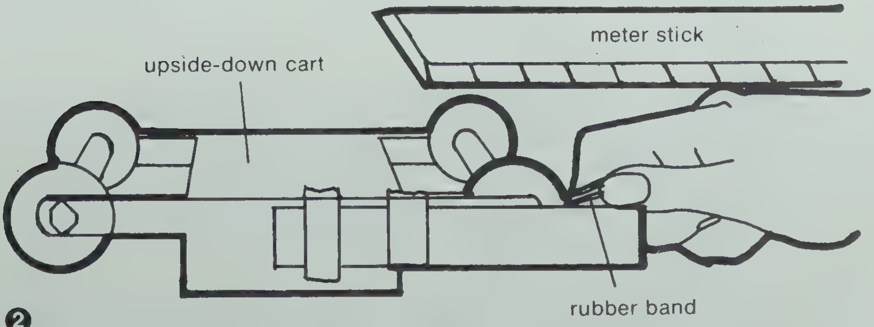
2. Use the rubber band to pull the cart 1 m. Record the length the rubber band is stretched to pull the cart (Table 10·4).

3. Pull the cart 1 m with the *force measurer.* Use Table 10·4 to record the *least* amount of force needed to pull the cart. ① Record the force readings in *newtons.*



①

4. Take the 1-kg mass out of the cart. Place the cart *upside down* on the table at one end of the meter stick. Repeat steps 2 and 3 above. ②



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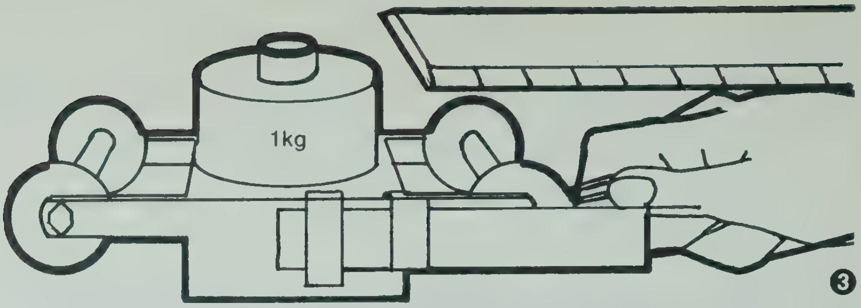


5. Return the cart to the end of the meter stick. Again turn it upside down. Place the 1-kg mass *on top of* the cart. Repeat steps 2 and 3 above. ❸

Observing . . .

Table 10·4

Position of cart	Rubber band extension	Force measurer reading, newtons
Upright with 1-kg mass	None	Very small force
Upside down empty	Medium	Larger force
Upside down with 1-kg mass	Very much	Much larger force

Interpreting . . .

Give a possible explanation for your observations.

Answers should convey an understanding that some sort of surface resistance exists (to a greater degree) when the upside-down carts are pulled.

Now read "The force that rubs the wrong way," pages 260–262 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Describe what happens when constant force is applied to a free-to-move object.
2. Predict how the speed of an object will be changed when the constant force on the object is changed.
3. Explain how the term "weight" is related to the term "force."
4. Predict the effect friction has on the motion of an object.

Name ______________________________

Date ____________ Class ____________

PROBLEM C: ***What is happening when you apply force without changing the motion of an object?***

This activity should be done by pairs of students. Once the equipment has been put together, the activity takes very little time. If you do not have enough force measurers, have pairs of students take turns using the ones that are available.

Materials:
2 Force measurers, 0–20 N
1 Motion cart
1 Metric ruler
1 Kilogram mass
String

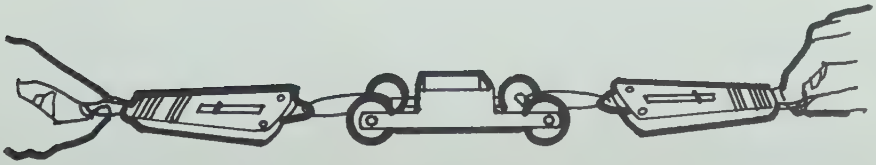
Investigating . . .

1. Take two force measurers that are alike. Tie a force measurer to each end of a motion cart as follows: Remove the hook attached to the end of the spring on the measurer. Thread string through the hole in the measurer. Tie the string around the axle of the motion cart.

2. Put the cart in the center of a table. Hold the free end of one force measurer in your right hand. Your lab partner should hold the free end of the other measurer in the same way.

3. Pull gently on each of the force measurers. Record whether or not the cart moves and the direction in which the cart moves (Table 10•5). Also record the readings on the force measurers.

4. Stretch both force measurers and hold them steady. Record the reading on each force measurer.



5. Gently reduce the pull on the right-hand force measurer until there is no more force on this side of the cart. Record any movement of the cart and the reading on the force measurers during that movement.

Repeat the activity with a 1-kg mass in the cart.

Observing . . .

Table 10·5

	Force measurer on left, newtons	Force measurer on right, newtons	Direction of motion, if any
Empty Cart: Equal force	Variable	Variable	Variable
Unequal force			
Cart + 1-kg mass: Equal force	The force measurer toward which the cart moved should have a higher reading.		
Unequal force			

Interpreting . . .

1. How did the force on one side of the cart compare with the force on the other side when the cart did not move?

   The force on each side of the cart was the same. The cart didn't move because it was being pulled equally in both directions.

2. Use your observations to explain why the cart moved in some cases.

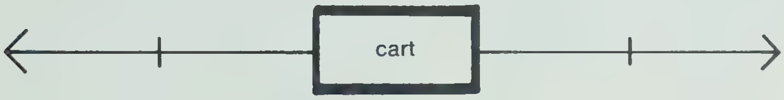
   The force in the direction in which the cart moved was greater.

Name ______________________

Date __________ Class __________

Tying ideas together:

When people talk about forces, they often use arrows to represent the forces. The length of the arrow shows how much force is being put on an object. The direction of the arrow shows the direction in which the force is being applied. Each force applied in this problem can be represented by an arrow.



Assume that each section in the length of the force arrow stands for a force of 0.5 newton on the cart.

Now use your observations in Problem C. Draw a force diagram for each of the following situations:

1. *The first time the empty cart moved while two of you were pulling on it.*
   Use a scale in which each 0.5 cm of arrow length = 1 newton.

   Variable. Should show cart with arrow on each side. Longer arrow should be in direction of motion.

2. *The first time the empty cart did not move when two of you were pulling on it.*
   Use a scale of 0.5 cm = 1 newton.

   Variable. Should have equal arrows, one on each side of cart.

Before you continue, read "Force on the straight and narrow," pages 263–266 in your text.

Name ____________________

Date __________ Class __________

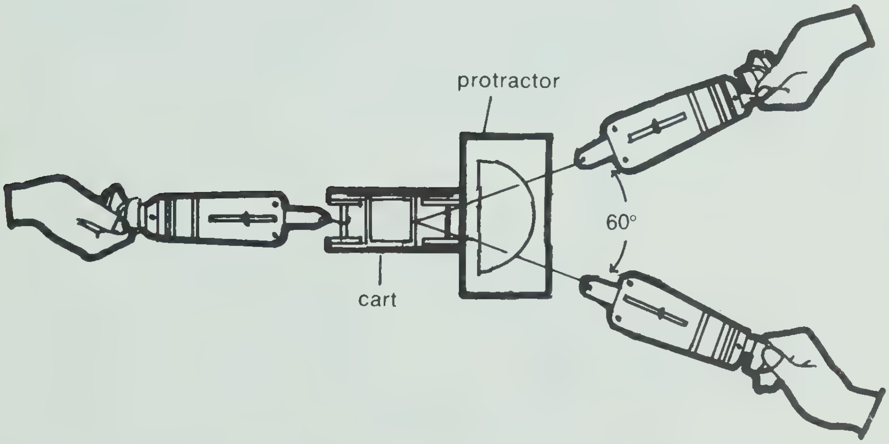
PROBLEM D: ***What happens when you apply force at an angle?***

This activity should be done by groups of 3 students. If you do not have enough force measurers, have the groups take turns using the ones that are available.

Materials: 1 Protractor (See Chapter 2, Problem A.)
3 Force measurers, 0–20 N
1 Motion cart

Investigating . . .

1. Hook two spring force measurers to the front of a motion cart and one to the back. One person should hold each force measurer. The front measurers should be about 60° apart. Use a protractor to check the angle.



NOTE: Turn to page 245 to find clues for using a protractor.

Refer students having trouble with using protractors to page 245 in the Appendix.

2. Hold the measurer at the back of the cart firmly in place. Pull the measurers at the front of the cart so they each show a force of 5 newtons. Now record the reading on the *back* force measurer in Table 10·6.

3. This time hold the front force measurers about 140° apart. Repeat step two. Record the reading on the back force measurer in Table 10·6.

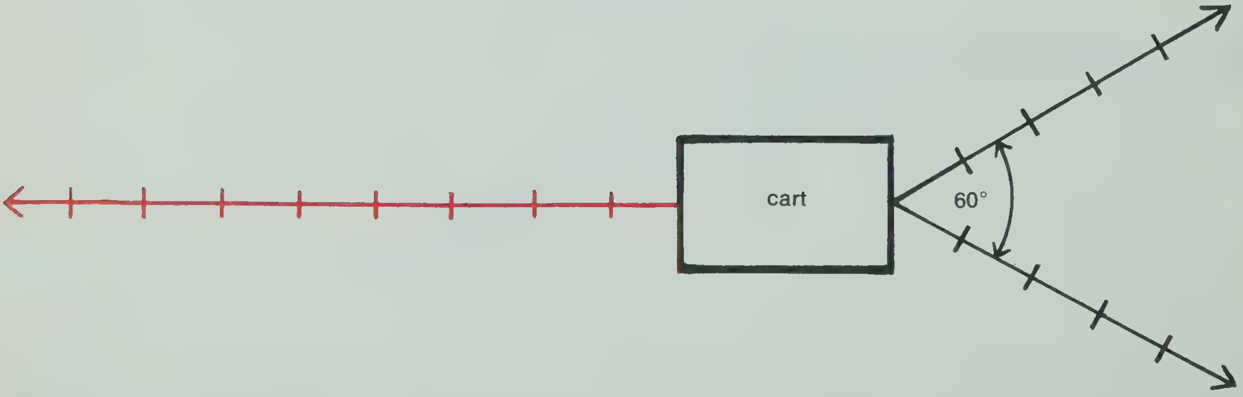
Observing . . .

Table 10·6

Angle between front measurers	Reading on front measurers	Reading on back measurer
60°	5 newtons	8.7 newtons
140°	5 newtons	3.9 newtons

Interpreting . . .

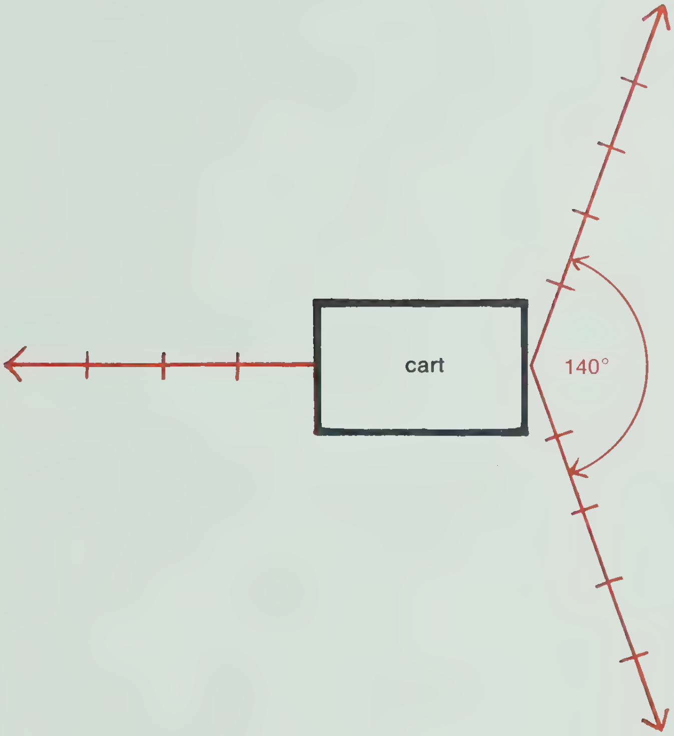
1. Make arrows to show direction and force.
   (a) Use the data in Table 10·6 to show the direction and force of the measurer on the back of the cart. Let 1 cm equal 1 newton of force.



Name ______________________

Date ___________ Class ___________

(b) Use the data in Table 10·6 to show direction and force of the two measurers held at 140°. Show direction and force of the back measurer. Let 1 cm equal 1 newton of force.



2. When force is exerted at each end of a cart, without the cart moving, the two forces are equal. (Check your results for Problem C.)

   In both setups for Problem D, you pulled from the front with what seemed to be a total force of 10 newtons. Was the force on the back ever equal to 10 newtons when the cart wasn't moving? Try to explain your results.

   No. Because the two forces at the front are at an angle to each other, the effect is less than 10 newtons.

3. Was more or less force needed in your second trial to balance the 10 newtons at the front of the cart? Why do you think so?

   Less, because the 5-newton forces were at a greater angle to each other.

YOUR TURN: ***How do forces at an angle work when the forces are unequal?***

Design an experiment using the motion cart and three force measurers that will show what happens when one of the two front force measurers is exerting more force than the other one. Use force arrows to show your results.

Now read "Forces at an angle," pages 267–270 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Predict the effect two equal or unequal forces will have on the motion of an object when the forces are exerted on opposite sides of an object.

2. Describe the total effect that forces acting at an angle to each other will have on an object.

Name ______________________

Date __________ Class __________

CHAPTER 11: DOING WORK

Let each group use the same cart, bag of washers, and pulleys throughout this chapter.

BEFORE YOU BEGIN PROBLEM A . . .

Read "Doing Work," page 271 in your text.

Then take some pulleys and string, and a ring stand. Try to use the pulleys and string to lift some things in the classroom. Vary the number of pulleys. Wind the string in different ways. Lift the same objects using each setup. Notice any differences.

Now think about these questions:

—Why does a crane have pulleys?

—How do young children adjust a seesaw when they are playing with someone lighter?

—Does it take more effort to climb stairs or to walk up a ramp to the next floor?

PROBLEM A: *What do you "save" when you use a pulley?*

Materials:

- 1 Motion cart
- 1 Felt-tip pen
- 1 Force measurer, 0–20 N
- 1 Force measurer, 0–2.5 N
- 1 Plastic bag
- 1 Ring stand and ring
- 1 Set of standard masses
- 1 Meter stick
- 2 Single pulleys
- 2 Double pulleys
- 1 Equal-arm balance
- String
- Washers

I Investigating . . .

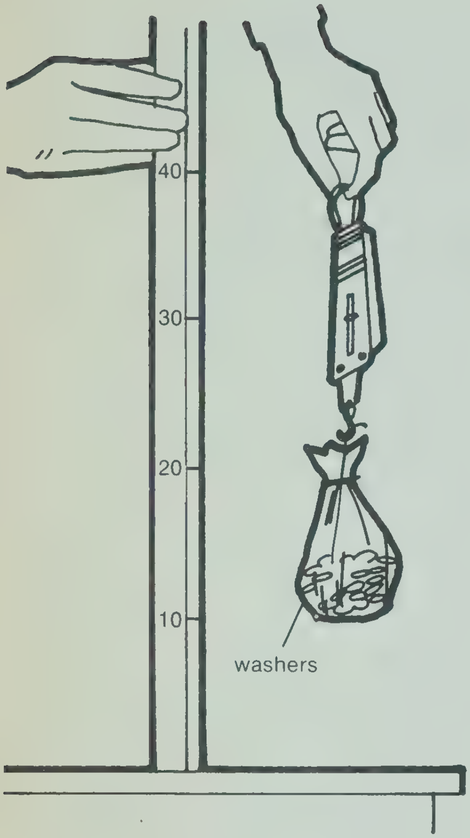
1. Place your motion cart on the left pan of an equal-arm balance. Put a plastic bag and a piece of string on the other pan.

Note: Turn to page 253 to find clues for using an equal-arm balance.

Refer students having trouble with using an equal-arm balance to page 253 in the Appendix.

2. Fill the plastic bag with washers until the mass of the bag, washers, and string is equal to the mass of the cart.

3. Tie a loop in one end of the string. Use the other end of the string to tie the bag.



4. Hook a spring force measurer to the loop in the string. Lift the bag of washers 0.1 m (10 cm). Record the force needed to lift the washers (Table 11•1). That force is the *weight* of the bag of washers.

The mass of the cart is the same as the mass of the bag of washers. Therefore, the force needed to lift the cart is the same as the force needed to lift the washers. And the *weight* of the cart is the same as the weight of the washers.

Observing . . .

Table 11•1

Force on measurer, newtons	Upward distance washers move, m
Depends on cart being used	0.1

Interpreting . . .

Every time you lift an object, you do *work*. You can figure out how much work you did on the washers. Multiply the force you used to lift the washers by the upward distance the washers moved.

WORK = FORCE × UPWARD DISTANCE

Use Table 11•2 to figure out how much work you did when you used force to lift the washers 0.1 m. The unit of work is called the *newton–meter* (N•m).

Refer students having trouble with decimals to page 241 in the Appendix.

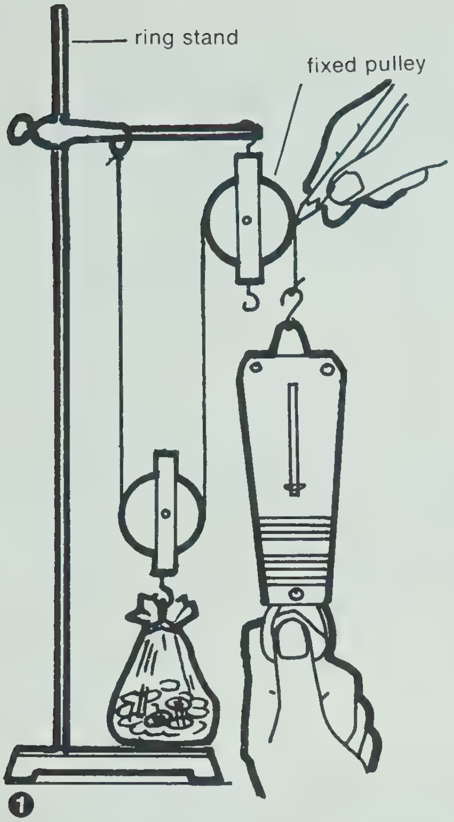
Note: Turn to page 241 to find clues for multiplying decimals.

Table 11•2

Force to lift washers, newtons	×	Upward distance washers move, meters	=	Work done on washers, N•m
Variable	×	0.1	=	Variable

Name ______________________

Date ____________ Class ____________



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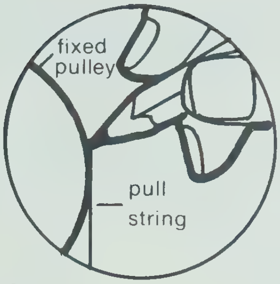

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II Investigating . . .

1. Now use two pulleys to do work. Use a ring stand and string to set up the system of two pulleys as shown. ❶

A pegboard setup can be used to support the pulleys if you have one available.

Note: Make sure the ring stand is steady on the table.

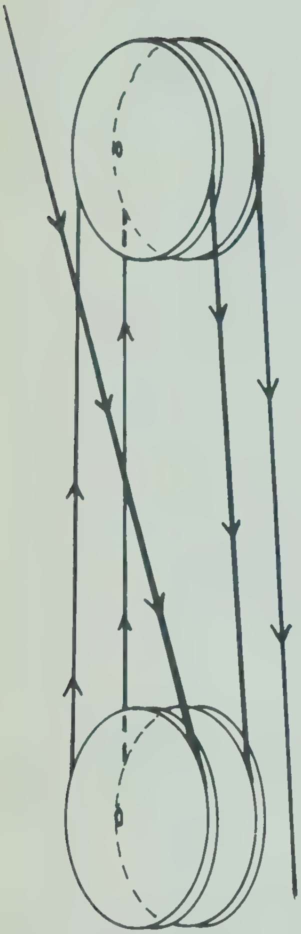
2. Mark the *pull string* at the top of the upper pulley with a marking pen. ❷

3. Tie a knot in the pull string about 2 cm below the upper pulley. Attach your force measurer through the knot.

4. Now get ready to do three things:

   a) Pull down slowly on the force measurer with a constant force to lift the bag of washers 0.1 m. Record the force it takes to lift the washers in Table 11·3.

   b) While the bag of washers is being held at 0.1 m, mark the string again at the top of the upper pulley.



❸

c) Now measure the distance between the two marks on the string. Record the distance in Table 11·3. It is the distance you applied force to the washers.

Repeat the activity, using four pulleys. ❸ Record your measurements in the same table.

Observing . . .

Table 11·3

No. of pulleys	Force to lift washers, newtons	Distance between marks on string, m
2	0.5 of the force in Table 11·1.	0.2
4	0.25 of the force in Table 11·1.	0.4

Interpreting . . .

How much work did *you* do to lift the washers 0.1 m? Figure it out by filling in Table 11·4. Work = force applied × distance force applied.

Table 11·4

No. of pulleys	Force applied, newtons	×	Distance force applied, meters	=	Work done by you, N·m
2	Variable	×	0.2	=	See Table 11·2
4	Variable	×	0.4	=	

Name ____________________

Date __________ Class __________

Tying ideas together:

The weight of the bag of washers has not changed during this activity. The distance the bag of washers was lifted (0.1 m) did not change either.

a) How much work did it take to lift the washers without pulleys?

See Table 11•2, page 138.

The nylon pulleys we used were almost frictionless. Therefore our inexpensive force measurers did not show any differences in force caused by the friction in the pulleys.

b) Did the pulleys save any work?

No. If there was any friction, the use of pulleys required more work.

c) How much force was required to lift the cart in each situation in Tables 11•1 and 11•3?

See Tables 11•1, page 138, and 11•3, page 140.

d) Why do you think pulleys are useful? (Use your answers to parts a-c to help you.)

Less force is needed to do the same amount of work.

Before you continue, read "How to lift a small elephant single-handedly," "What have you done?" and "Input versus output" on pages 272–279 in your text.

YOUR TURN: ***Is there any advantage to using only one pulley?***

Set up a ring stand and a single pulley. Mark the pull string at the top of the pulley with a marking pen.

Tie a loop in the string about 2 cm below the pulley. Attach your force measurer through the loop. Use the force measurer to raise the bag of washers 0.1 m (10 cm).

Make a hypothesis about the effect of using only one pulley. Test your hypothesis.

Name ______________________

Date ___________ Class ___________

PROBLEM B: *What do a seesaw and a ramp have in common with a pulley?*

Materials:	1 Ring stand and ring	1 Motion cart
	1 Force measurer, 0–20 N	1 Ruler
	1 Force measurer, 0–2.5 N	String
	3 Meter sticks	Books
	1 Laminated board (80 × 15 × 0.5 cm)	
	Bag of washers from Problem A, page 137	

I Investigating . . .

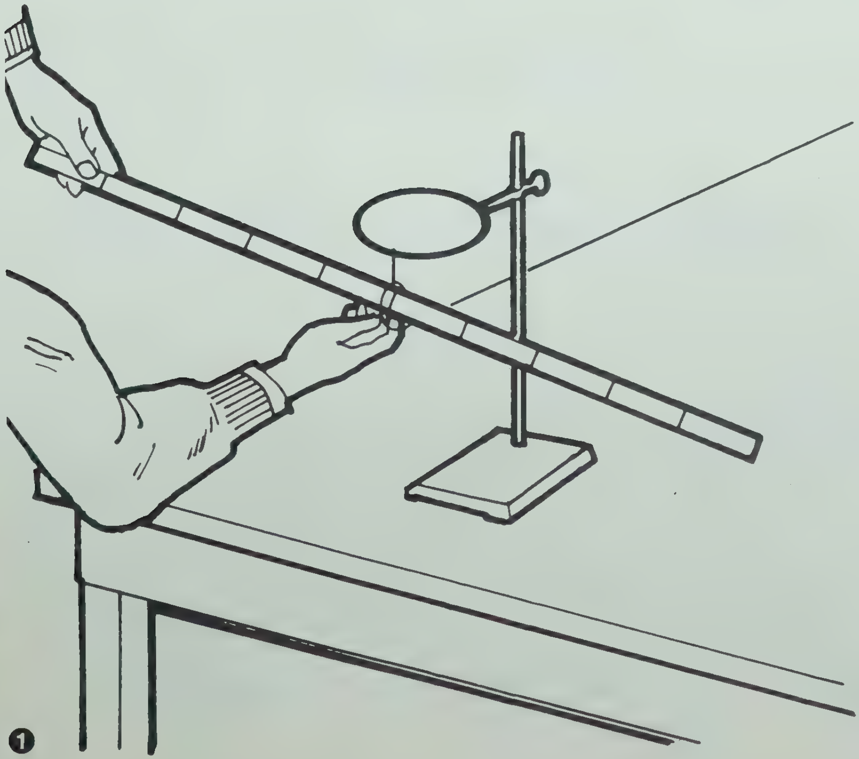
Four people are needed to do this experiment. Split the work among the members of your lab group.

This activity requires at least 4 students: 1 to keep the cart on the lever, 1 to pull down and read the force measurer, and 2 to measure distance each end of the lever moves.

1. Use a meter stick, string, and ring stand to make a seesawlike device called a *lever*. Here's how:

   Make a loop with string and slip the meter stick through the loop. Tie the other end of the string to a ring stand. Slide the meter stick to the 50-cm mark as shown. The point at which the meter stick (or lever) is supported by the string is called a *fulcrum*. ❶

Explain that the place where the meter stick is hung is the fulcrum of the lever.



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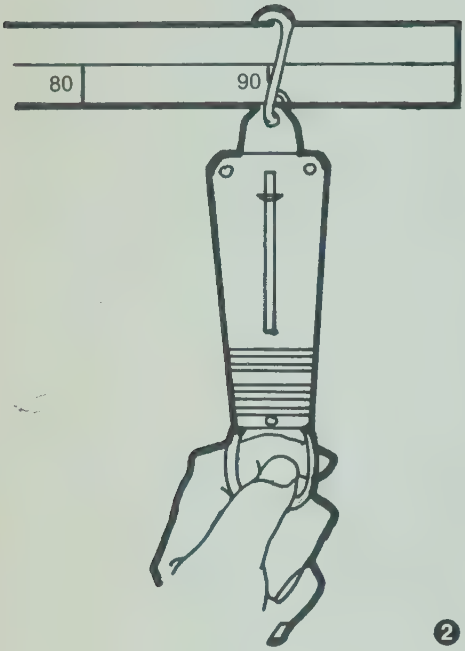


❷

2. Now take the bag of washers from Problem A. Use the loop in the string to hang the bag at the 10-cm mark on your meter stick. Tape the loop in place. Hook a force measurer at the 90-cm mark. ❷

3. Pull down gently on the force measurer to lift the washers 0.1 m.

4. Measure the force used to pull the free arm of the lever down. And measure the distance the 90-cm mark drops to lift the washers 0.1 m. That distance is the distance you applied the force. Record both measurements in Table 11•5.

Repeat the activity two more times. First, place the bag of washers at the 30-cm mark. Record the force needed to lift the washers 0.1 m (Table 11•5). And, in the same table, record the distance the 90-cm mark drops.

Return the washers to the 10-cm mark and place the force measurer at the 70-cm mark. Record the force needed to lift the washers and the distance the 70-cm mark drops.

Observing . . .

Table 11•5

Washer position	Force measurer position	Force applied, newtons	Distance force applied, m	Upward distance washers move, m
10 cm	90 cm	Weight of washers	0.1	0.1
30 cm	90 cm	Variable	Around 0.2	0.1
10 cm	70 cm	Variable	About 0.05	0.1

Name ____________________

Date __________ Class __________

Interpreting . . .

1. Use Table 11·6 to figure out how much work *you* did on the bag of washers.

Table 11·6

Force applied, newtons	×	Distance force applied, m	=	Work done by you, N·m
Weight of washers	×	0.1	=	Should be same as or more than work in Table 11·2, page 138.
Variable	×	Around 0.2	=	
Variable	×	Around 0.05	=	

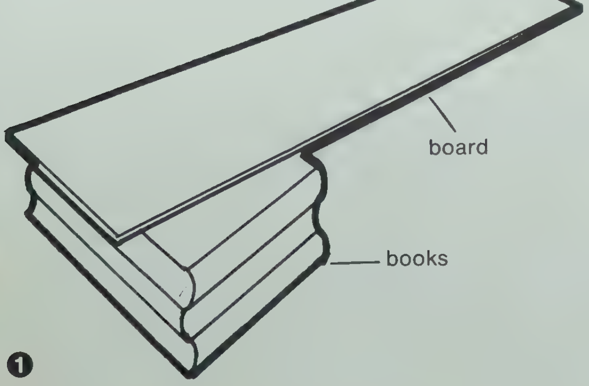
2. The work needed to raise the washers 0.1 m has not decreased since Problem A, Investigating I. Use Table 11·2, page 138, and Table 11·6 to explain any advantage you see in using a lever.

You need less force to do the same work if you apply the force at a greater distance from the fulcrum than the distance of the object you are lifting.

Before you continue, read "A machine can be very simple" and "The lever, or lifting the world," pages 280–283 in your text.

II Investigating . . .

1. Stack some books under one end of a board to make an *inclined plane* as shown. ❶ The top of the pile of books should be 0.1 m high. Draw a line every 10 cm along the length of the board. ❷



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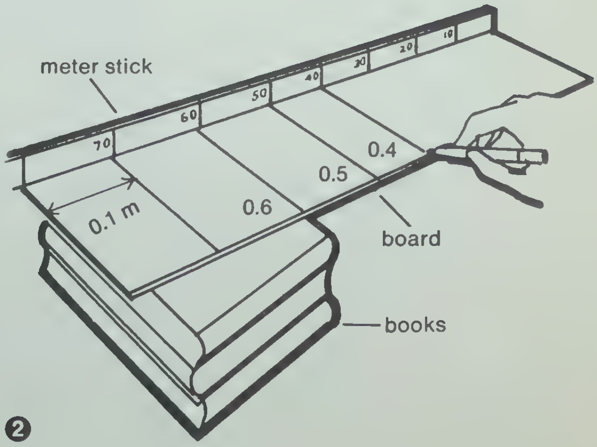

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2. Position the board so that the 0.6-m line is at the edge of the stack of books (see fig. 2).

3. Now, hook the force measurer to your motion cart. Use it to pull the cart up the ramp. Record the force needed to pull the cart 0.6 m up the ramp in Table 11·7.

Do the activity two more times. But change the position of the board each time. The second time have the 0.5-m line at the edge of the stack of books. The third time have the 0.4-m line at the edge of the stack of books (see fig. 2).

Observing . . .

Table 11·7

Force applied, newtons	Distance you applied force (incl. length of ramp), m	Upward distance cart moves, m
Variable	0.6	0.1
	0.5	0.1
	0.4	0.1

Interpreting . . .

1. How much work did *you* do to pull the cart up each ramp to a height of 0.1 m? (In this case, the distance you applied force is the length of the ramp.) Fill in Table 11·8 to find how much work you did.

Name ______________________

Date __________ Class __________

Table 11·8

Force applied, newtons	×	Distance you applied force, m	=	Work done by you, N·m
Variable		0.6		Same as or more than work in Table 11·2, page 138.
		0.5		
		0.4		

2. The mass of the cart is the same as the mass of the bag of washers. The work to raise that mass 0.1 m has not changed since Problem A, Investigating I, page 138. Why would you bother to use the ramp?

   Less force is needed to do the same work.

Before you continue, read "A new slant on work," pages 284–285.

Tying Ideas Together:

1. Do you make less work for yourself if you change a simple machine so it is easier to use? In other words, does it help to add pulleys, move the fulcrum closer to the object being lifted, or lower the angle of the ramp? Explain why or why not.

   No. Variable answers should all get at the idea of less force being applied over a greater distance.

Get at the idea of a simple machine being a *force* "saver"—not a work saver.

2. *Work input* is defined as the work you do. *Work output* is defined as the end result.

   In this problem you did work with two different simple machines. The end result (work output) was always the same. The same weight (motion cart) was raised the same distance (0.1 m).

Would it be safe to say that work input = work output?

Justify your answer by using your data in Tables 11·6 and 11·8.

Yes, when there is no friction. Work done always is the same as the weight of the cart times the distance it is lifted.

Alt. answer: No, when friction is present. In this case, work done is more than the work output.

Before you continue, read "The advantage of simple machines," page 288.

YOUR TURN: ***How much work do you do going up steps?***

A stairway is an inclined plane that helps you get from one floor to another.

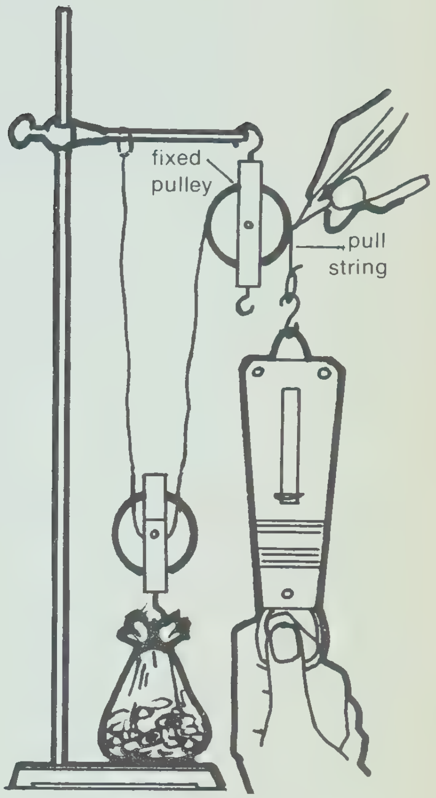
Measure the vertical height of a stairway. Compute your weight in newtons (one pound = 4.5 newtons). Walk up the stairway. Compute how much work you did.

(Work = Vertical height in meters × Weight in newtons.)

Name ____________________

Date __________ Class __________

PROBLEM C: ***How does friction affect work input?***



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Materials:

- 1 Ring stand and ring
- 1 Force measurer, 0–20 N
- 1 Force measurer, 0–2.5 N
- 2 Single pulleys
- 2 Double pulleys
- 1 Laminated board (80 × 15 × 0.5 cm)
- Bag of washers from Problem A, page 137
- 1 Motion cart
- 1 Ruler
- Felt-tip pen
- String
- Books

I **Investigating . . .**

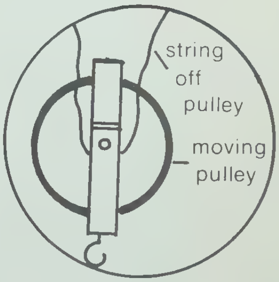
1. Use a spring force measurer to lift the bag of washers 0.1 m. Record the amount of force needed to lift the washers (Table 11•9). If you did this in Problem A, page 137, copy the results.

2. Set up the system of two pulleys as shown. ① Slip the string off the wheel of the moving pulley. ②

3. Use a marking pen to mark the string at the point where it goes over the top pulley. Tie a knot in the string about 2 cm below the upper pulley. Attach your force measurer through the knot.

4. Pull on the force measurer to lift the washers 0.1 m. Again mark the string at the point where it goes over the top pulley.

5. Record the force it took to raise the washers (Table 11•10). Also record the distance between the marks.



②

Do the same thing, using four pulleys. Again slip the string off the wheels of the moving pulleys.

Observing . . .

A. Table 11•9

Force on measurer, newtons	Distance force applied, m	Upward distance washers move, m
Variable	0.1	0.1

Work output = force × distance =

B. Table 11·10

	Force applied, newtons	Distance force applied, m
2 pulleys	Variable	0.2
4 pulleys	Variable	0.4

Interpreting . . .

1. The work output was calculated in section A above. Use Table 11·11 to figure out the work input when you used two and four pulleys.

Table 11·11

	Force applied, newtons	×	Distance force applied, m	=	Work input, N·m
2 pulleys	Variable	×	0.2	=	Much more than work output
4 pulleys	Variable	×	0.4	=	

2. Compare the work input to the work output.

   The work input is greater than the work output.

II Investigating . . .

1. Set up an inclined plane as in Problem B, Investigating II, page 145. Have the 0.6-m line on the ramp at the edge of the stack of books.

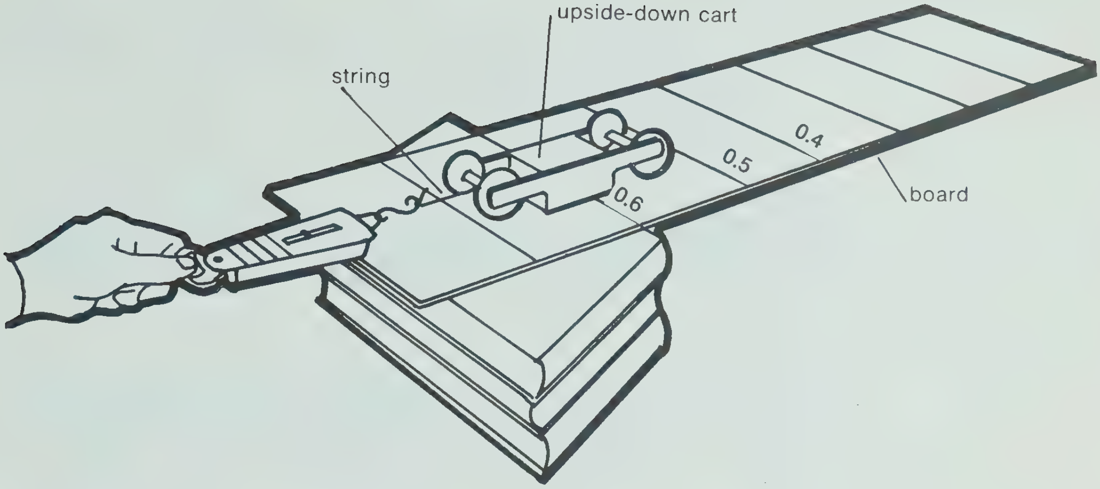
2. Turn the cart over so that the wheels are up in the air. Hook the force measurer to the cart.

3. Pull the cart up the ramp. Record the amount of force needed to pull the cart up the ramp (Table 11·12).

Repeat the activity, but put the 0.5-m line on the ramp at the edge of the stack of books.

Name ______________________

Date __________ Class __________



Observing . . .

Table 11·12

Force applied, newtons	Distance force applied, m
Variable	0.6
	0.5

Interpreting . . .

1. The mass of the cart is the same as the mass of the bag of washers. The work output (work done on that mass) was found in Table 11·9. How much work input did you supply using an inclined plane? Use Table 11·13 to find out.

Table 11·13

Force applied, newtons	×	Distance force applied, m	=	Work input, N·m
Variable	×	0.6	=	More than work output
	×	0.5	=	

2. Compare the work output to the work input.

   Work input is greater than work output.

Before you continue, read "Lost work," pages 288–289.

Tying ideas together:

1. The efficiency of a machine is defined as:

$$\frac{\text{WORK OUTPUT, N}\cdot\text{m}}{\text{WORK INPUT, N}\cdot\text{m}} \times 100 = \underline{\hspace{2cm}}\ \%$$

Refer students having trouble with decimals to page 241 in the Appendix.

Note: Turn to page 241 to find clues for dividing decimals. Fill in Table 11·14 to find the efficiency of each machine used in this problem.

Table 11·14

Machine	Work output	Work input	Efficiency, %
2 pulleys	Same as in Table 11·9	Same as in Table 11·11	Variable
4 pulleys			
0.6-m ramp		Same as in	
0.5-m ramp		Table 11·13	

2. Calculate the efficiency of the 2-pulley system in Problem A. Use Table 11·4, page 140, to find the work input. The work output is the same as that in Table 11·14. Compare the efficiency of this 2-pulley system with that of the 2-pulley system in Table 11·14.

   The efficiency of the 2-pulley system in Problem A is almost 100%. The system in Table 11·14 is less efficient. There is less friction when the string turns on the wheel of the pulley. Less force is used to overcome friction.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Set up and use three simple machines—the inclined plane (ramp), pulley, and lever.
2. Calculate work input.
3. Calculate work output.
4. Calculate the efficiency of a simple machine.

Name ______________________

Date ____________ Class ____________

CHAPTER 12:
WHAT GOES UP, MUST COME DOWN

BEFORE YOU BEGIN PROBLEM A . . .

Read "What Goes Up, Must Come Down," "Work, falling people, and dropping things," and "What is needed for work?" pages 299–302.

Then put two round bar magnets on the table. If the table is made of metal, put the magnets on top of a book. Place them so that opposite poles are touching each other. Pull them about 0.5 cm apart. Let go of them. What happens?

Lift your pencil 2 or 3 cm off the table. Let go of it. What happens?

Now think about these questions:

—Did it take work to pull the magnets together?

—Did it take work to make the pencil fall?

—Who or what did that work?

PROBLEM A: *Can magnets exert a force?*

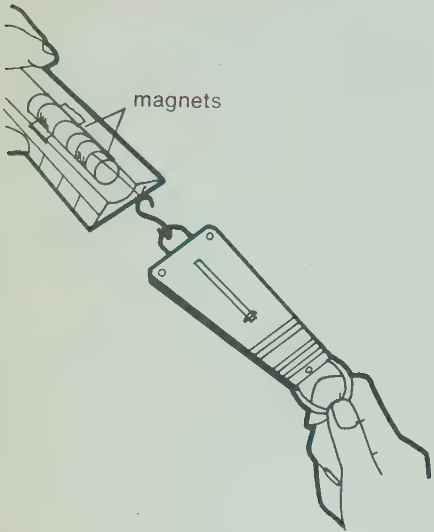
Materials: 1 Grooved plastic ruler
2 Round bar magnets
1 Force measurer, 0–20 N
1 Force measurer, 0–2.5 N
1 Iron nail
Tape
String

Investigating . . .

1. Take two round bar magnets and a plastic ruler with a groove in it. Place the magnets in the groove with opposite poles touching. If your desk is metal, place the ruler and magnets on top of a book.

Have pairs of students work together. One should pull magnets apart while the other reads the force measurer. Both should record the data.

Students can get idea of effect of friction by pulling magnet or nail in groove when it is outside the field of the taped magnet.



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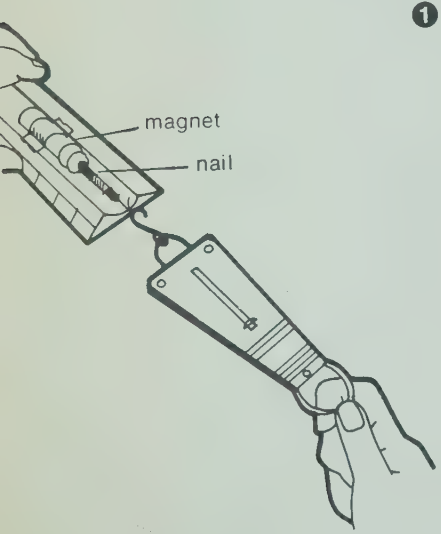


❷

2. Tape one magnet in place on the ruler. Tape a string to the other magnet. ❶

3. Hold the ruler in place and use your force measurer to slowly pull the magnets apart. Record the greatest amount of pull on your force measurer while the magnets are still touching (Table 12•1).

4. Place a pencil between the magnets and repeat the above procedure. If the highest reading on your force measurer is less than 2.5 newtons, repeat the activity with a 0–2.5 newton force measurer. Record the highest reading in Table 12•1.

Repeat the procedure two more times, with two pencils between the magnets and with three pencils between the magnets. Record the forces in Table 12•1.

5. Now remove one magnet. Put an iron nail in the groove next to the magnet taped in place. Attach a string to the nail. ❷

Repeat the procedure you used with the two magnets. Record the forces in Table 12•2.

Observing . . .

A. Table 12•1

Distance between magnets	Force of attraction
0	Variable. Decreases with distance.
1 pencil	
2 pencils	
3 pencils	

Name ____________________

Date __________ Class __________

B. Table 12·2

Distance of nail from magnet	Force of magnet
0	Variable. Decreases with distance.
1 pencil	
2 pencils	
3 pencils	

Interpreting . . .

1. Does the force of attraction between the magnets change as you separate them? If so, how does the force change?

   Yes. It decreases.

2. Does the magnet always attract the nail with the same force? Use your observations to justify your answer.

   No. The force varies with the distance. The farther apart they are, the less force.

3. Does a magnet do work (a) when it attracts another magnet, (b) when it attracts a nail? Justify your answer.

   (a) Yes. (b) Yes. It exerts a force over a distance.

Before you continue, read "Forces where no objects touch," pages 302–304 in your text.

Name ______________________

Date __________ Class __________

PROBLEM B: ***What do you get in return for work (besides money)?***

Materials:
2 Metal tracks, 2 meters long
2 Plastic rulers with grooves down the center
1 Bag of glass marbles
1 Bag of ball bearings
1 Meter stick
1 Book, 2 cm thick
1 Equal-arm balance and masses
1 Force measurer, 0–2.5 N

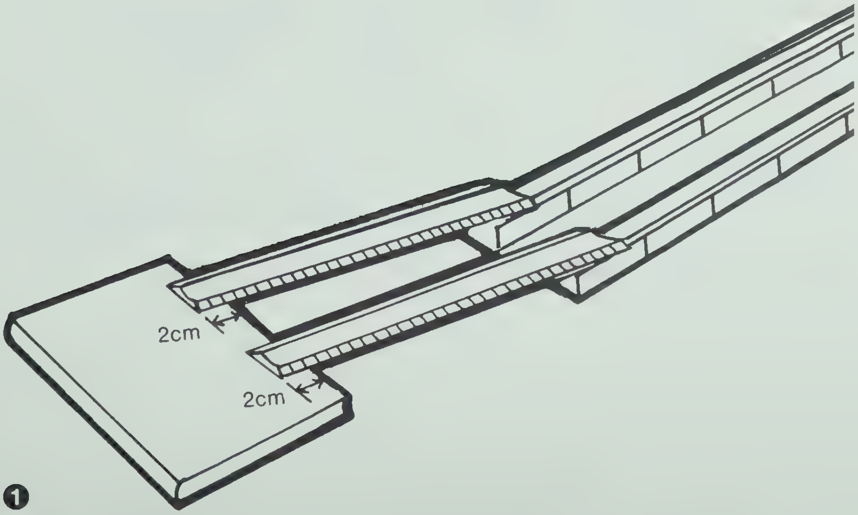
Investigating . . .

1. Work with another laboratory group. Set up two tracks as shown. ❶ Be sure that the height of the book above the tracks is no more than 0.5 cm. Have the tracks and rulers parallel to each other. The edge of each ruler should be 2 cm from the edge of the book.

The book should be very close to 0.5 cm above the track. The students may have to use a stack of paper or a thin book.

The track must be level for this experiment. If any students get unusual results, check the surface under their tracks with a carpenter's level and adjust the track accordingly.

Students will probably be unable to measure the weight of single marbles in newtons. They have been instructed to weigh a sack full of identical marbles and divide by the number of marbles in the sack to find the weight of one marble. Put twenty marbles in each sack so that it will not be empty after all the groups remove their marbles. Use a lightweight plastic sack so its weight can be discounted.



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2. Use your force measurer (spring scale) to find the weight (in newtons) of the bag of marbles. ❷ Divide the weight of the bag of marbles by the number of marbles in that bag. You will then know the weight of each marble in that bag. Record the weight in Table 12•3.

3. Do the same with the bag of ball bearings.

❷

For more information on the spring force measurer, refer students to the "Your Turn" on page 126.

Demonstrate how to read the scale on the force measurer in newtons.

4. Now take one marble and one ball bearing from each bag. Find the mass of each. Record it in Table 12·3.

5. Let one marble and one ball bearing roll down each ruler from the edge of the book at the same time. Note whether the marble and ball bearing roll down the rulers together. Measure how far each travels along its track. Record this information in Table 12·3.

Let the marble and ball bearing roll down the tracks two more times. Record the distance they traveled (Table 12·3).

Observing . . .

Table 12·3

	Mass, kg	Weight, newtons	Distance traveled, meters		
			Trial 1	Trial 2	Trial 3
Marble	Variable	Variable	Variable. Ball bearing should travel farther each time.		
Ball bearing					

Interpreting . . .

1. Which object rolled the longest way down the track?

   The ball bearing.

2. Make a statement that will relate the mass of an object to the force needed to lift it.

   The greater the mass of an object, the more force it takes to lift it.

Name ______________________

Date __________ Class __________

3. Work is force times distance. Which object took the most work to lift to the edge of the book? Give a reason for your answer.

The heaviest one. Both were lifted the same distance, but it took more force to lift the one with the greatest mass.

4. Make a generalization about your observations that takes into account the work needed to lift the objects and the distance they traveled.

The more work it takes to lift an object, the farther it will travel.

5. If you dropped both the marble and the ball bearing from the same height, which would hit the ground with the most force? Why?

The ball bearing. It took more work to lift it. It will fall hardest.

Now read "Getting something for work" and "Mass, weight, and energy in falling things," pages 306–310 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Calculate the forces of attraction between two magnets and between a magnet and an iron nail.

2. Demonstrate how work can result in motion.

UNIT 4: HEAT

Name ________________________

Date __________ Class __________

CHAPTER 13: TEMPERATURE

BEFORE YOU BEGIN PROBLEM A . . .

Read "Heat" and "Temperature," pages 320–324 in your text.

Then pick up an ice cube with one hand and touch a jar of hot water with the other hand. How does each hand feel? Now think about these questions:

—What is meant by the word "hot"?

—What is meant by the word "cold"?

—How do you measure hotness or coldness?

PROBLEM A: *Is your body surface an accurate thermometer?*

Materials: 3 Jars (1 liter) Water Ice cubes

Investigating . . .

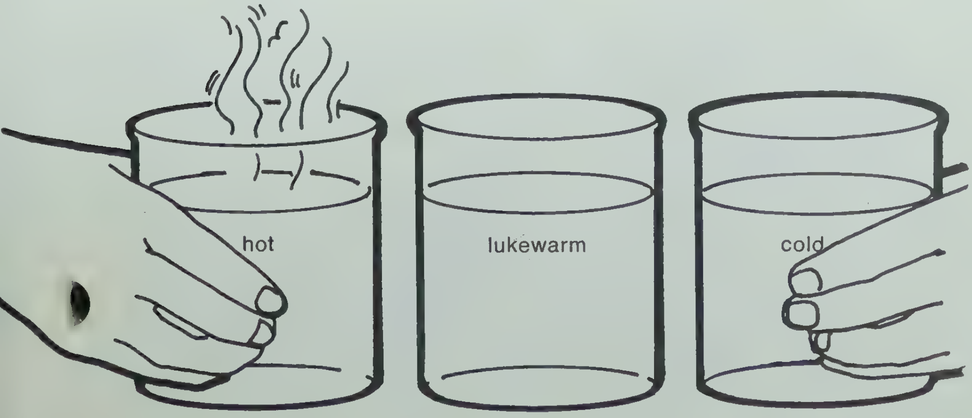
1. Add water of different temperatures to three jars. Fill the first jar with very cold water and add several ice cubes. Fill the second jar with lukewarm water. Fill the third jar with hot water.

Quart jars can be substituted for the liter jars.

It is recommended that a large container of hot water and a large container of cold water be prepared before class begins.

2. Line up the jars on the table. Hold one hand against the jar of cold water. Hold your other hand against the jar of hot water. Count slowly to 30. Remove both hands and place them against the jar of lukewarm water. Record how the jar feels (Table 13•1).

3. Remove your hands from the jar. Count to 30 and again touch the jar of lukewarm water. Record how the jar feels now.



Repeat the activity. But hold your hands against the other pairs of jars listed in the table. Write down your observations in Table 13•1.

Observing . . .

Table 13•1

Jars touched first	Jar touched next	What happens?	
Cold & hot jars	Lukewarm jar	Immediately:	Variable.
		After 30 seconds:	Jar feels lukewarm.
Cold & lukewarm jars	Hot jar	Immediately:	Variable.
		After 30 seconds:	Jar feels hot.
Hot & lukewarm jars	Cold jar	Immediately:	Variable.
		After 30 seconds:	Jar feels cold.

Interpreting . . .

Use your observations to answer the following questions:

1. Is your body surface a good thermometer? Give evidence to support your answer.

   No. Variety of answers should cite observations in Table 13•1.

2. When you walk into an air-conditioned store on a hot day, does the store seem *colder* immediately after you walk in or 10 minutes after you've been in the store? Explain your answer.

   The store seems colder immediately after you walk in. There is a contrast between the heat outside and the cold inside. So, the store "feels" colder than it really is. Your body adjusts to the change in temperature after you have been inside the store for a while.

Name ______________________

Date __________ Class __________

PROBLEM B: ***How can liquids and gases be used to measure temperature change?***

Materials:
- 1 One-hole stopper, #4
- 1 Erlenmeyer flask, 125 ml
- 1 Asbestos pad to fit ring
- 1 Ring to fit stand
- 1 Ring stand
- 1 Clamp
- 1 Clear plastic straw, 5-mm diameter
- Food coloring (or ink)
- 1 Beaker, 600 ml
- 1 Beaker, 250 ml
- 1 Felt-tip pen
- 1 Ruler
- Alcohol burner
- Water

The clear plastic straws should slide easily into the one-hole stoppers. If necessary, wrap the straws with tape so they fit tightly into the stoppers.

If glass tubing is used, it would be safer for the teacher to put the tubing into the one-hole stoppers.

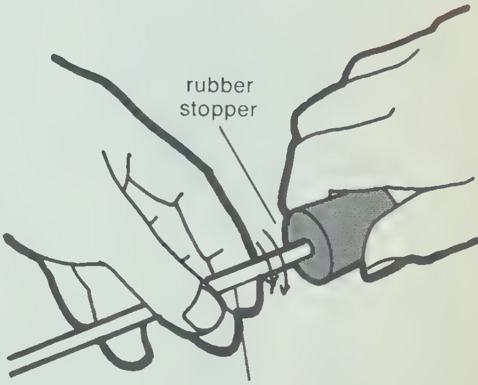
It is recommended that a large beaker of colored water be prepared before class begins.

I Investigating . . .

1. Push a clear plastic straw through a one-hole rubber stopper. Here's how:

   Wet the straw and the stopper. Push the straw very slowly and carefully. Gently twist the straw back and forth as you push. ❶ If you push too hard, the straw will bend or collapse.

2. Put the stopper and straw into your flask. Clamp the flask to a ring stand. Then fill a beaker with colored water. Put the beaker under the open end of the straw. Adjust the flask so the straw is under water. Measure and mark the level of water in the straw. ❷



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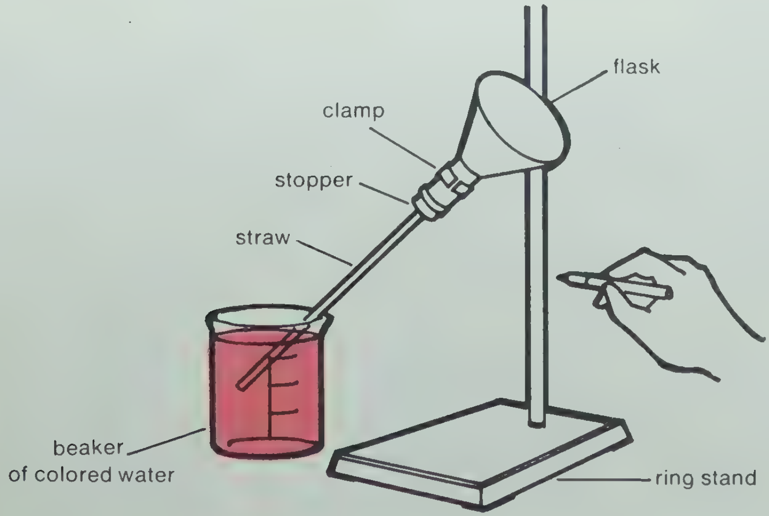

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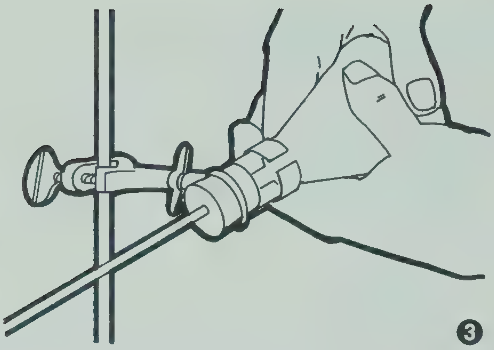
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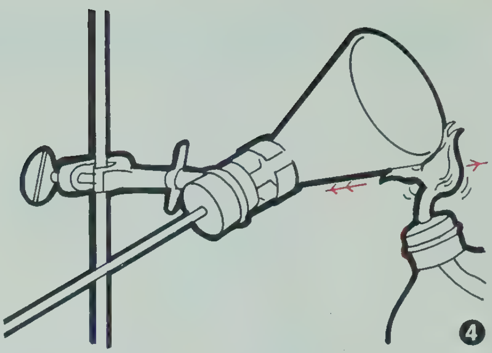
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You might want students to use safety glasses during this activity.

3. Hold the flask tightly for three minutes, so that your hands warm the glass. ❸ Note and mark any change in the water level in the straw. Record what happens (Table 13•2).

STOP

ALWAYS keep your hands, hair, and clothing away from an open flame.

ALWAYS keep the plastic straw away from the flame. The straw can catch fire.

4. Now, use your alcohol burner to heat the flask a little more.

   Pick up the burner. Move the burner up and down the length of the flask for about 10 seconds. ❹ Mark and record any further change in the water level. Allow the flask to cool. Measure the water level, and record your observations in Table 13•2.

Observing . . .

Table 13•2

Material tested	Effect of heating	Effect of cooling
The air in the flask	With hands: Variable. Bubbles come out of straw. With alcohol burner: Variable. Many bubbles come out of straw.	Variable. Water moves up the straw and into the flask.

Name ______________________

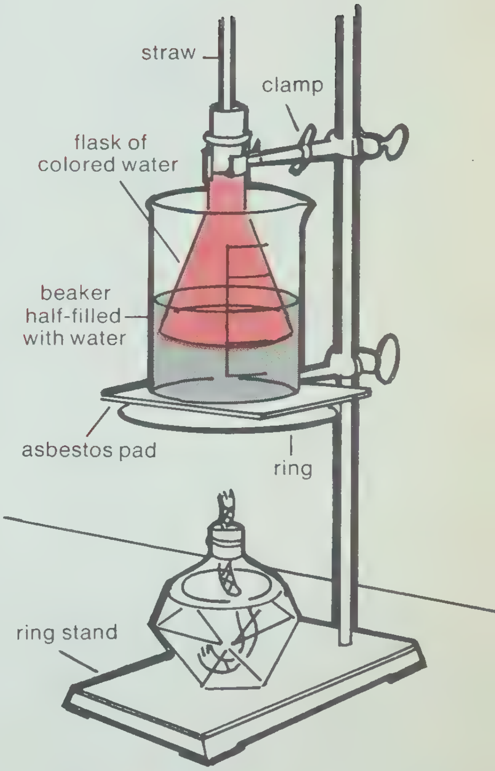
Date __________ Class __________

Interpreting . . .

What happened as the air in the flask was heated? Cooled?

As the air was heated it expanded and some air bubbles were pushed out of the straw and into the water.

As the air was cooled, it contracted. Because some air had bubbled out of the flask when it was heated, there was less air in the flask. Therefore the water rose up the straw into the flask.



II Investigating . . .

1. This time, fill the flask with colored water instead of with air. Again, push the stopper and straw into the flask.

2. Place the flask in a 600-ml beaker. Add water to the beaker until it is about half full.

3. Attach the ring to your ring stand. Put an asbestos pad on the ring. Then place the beaker (with the flask) on your ring stand. Clamp the flask so it does not touch the bottom of the beaker.

KEEP your face AWAY from the top of the straw.

ALWAYS use tongs to handle the hot flask and the beaker of hot water. Your hands can be burned touching hot equipment.

4. Use a marking pen to mark the level of the water in the straw.

5. *Gently* heat the beaker of water with an alcohol burner. Use your marking pen to indicate any change in the water level in the straw. Record your observations in Table 13•3.

Fill the flask to the top with colored water.

Students will probably need help in finding the proper level for the ring on the ring stand. Use the size of the heat source to determine where to put the ring. (See next page.)

It is important *not* to let the water boil. If it does, gas collects in the flask, under the stopper, where it cannot escape. The gas prevents the water in the tubing from returning to its original level.

6. Fill a beaker with ice water. Remove the flask from the hot water. Put the flask into the ice water so it is almost covered by the water. Again, use your marking pen to show any changes in water level. Record your results in Table 13•3.

Observing . . .

The height of the column depends on how long the flask is heated.

If the liquids are cooled *below* room temperature, they will fall *below* their original level.

Table 13•3

Material tested	Effects of heating	Effects of cooling
Water	Variable. Level rises.	Variable. Falls to original level.

Interpreting . . .

What happened as the water was heated? Cooled?

As the water was heated, it expanded and moved up the straw. As the water was cooled, it contracted and moved down the straw.

This question is based on the idea that mercury is a liquid. The fact that it is a metal is inconsequential.

Tying ideas together:

Many of the thermometers we use contain mercury—instead of air, alcohol, or water. Based on your observations, explain how you think a mercury thermometer works. (Hint: Mercury is a liquid.)

Mercury expands as the air temperature increases and warms the mercury. The mercury rises up the tubing, and the change in temperature is read in degrees. As the air cools, the mercury also cools and contracts. The mercury moves back down the tubing.

Before you continue, read "An effect of heat," pages 325–327 in your text.

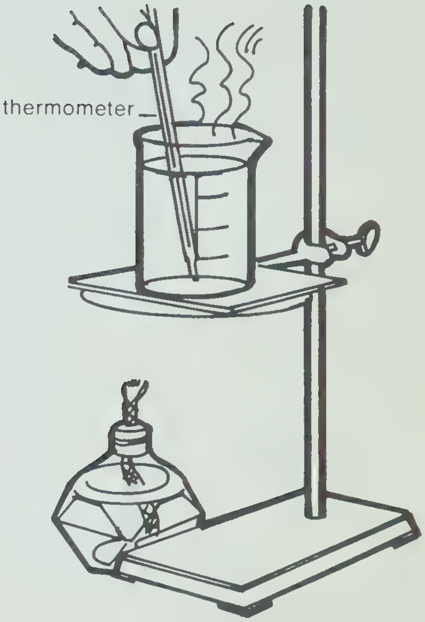
Name ____________________

Date __________ Class __________

PROBLEM C: *How do you make a scale for measuring temperature?*

Materials:

- 2 Beakers, 250 ml
- 1 Unmarked thermometer
- 1 Marking pen
- 1 Ruler
- 1 Stirrer
- Water
- Ice
- Alcohol burner



Investigating . . .

1. Fill one beaker with 200 ml of hot water. Heat the hot water until you see steam. Then move the alcohol burner away from the beaker.

2. Put an unmarked thermometer in the hot water. (If you use a thermometer with a scale, cover the scale with a strip of masking tape.) Hold the thermometer in the water until the mercury (or alcohol) stops rising. Mark this point.

3. Fill another beaker with 200 ml of cold water. Put two or three large ice cubes in the cold water. Stir until the ice is melted.

4. Put your thermometer in the cold water. Hold the thermometer in the water until the mercury (or alcohol) stops falling. Mark this point.

5. Use a ruler and marking pen to divide the space between the top and bottom marks into equal sections, or *degrees.* You may divide the space into as many or as few degrees as you want. You may also number your degrees any way you wish. Record your marks and numbering system on the blank thermometer in the laboratory book. Call the scale you have just made the "M" Scale (My Scale).

6. There are three beakers of water on the teacher's table. Use your "M" scale thermometer to measure the temperature of each beaker of water. Record the temperatures in °M in Table 13•4.

The temperature of the liquid must be taken from the *center* of the beaker, not while the bulb is resting on the bottom of the beaker.

Some students will mark the top of their temperature scales in warmer water, others in cooler water. The description of when to stop heating the water is intentionally vague.

Similarly, some students will use 2 ice cubes and others will use 3 ice cubes to cool their water. These instructions are also vague. The purpose of this activity is to have the students discover the need for standards of calibration.

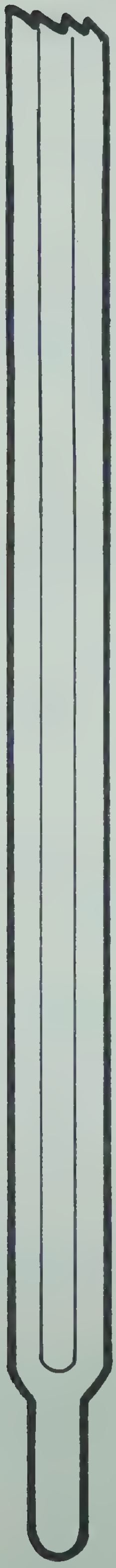
Prepare three beakers of water—one with boiling water, one with room-temperature water, and one with ice water.

Prepare the ice water and boiling water before class begins.

The student thermometers are *not* to be calibrated according to the freezing point and boiling point of water. Each student will probably have a different scale of temperature measurement.

Observing . . .

A.



"M" Scale

Name ____________________

Date __________ Class __________

B. Table 13·4

Beaker	Temperature, °M
1	Variable
2	
3	

C. How does your "M" scale compare with the "M" scales of other students?

Students should have different "M" scales. The numbering systems may be different. The space between degrees, i.e., number of degrees, may also be different.

Interpreting . . .

1. What would happen to the accuracy of your scale if you made the scale without using a ruler?

The scale would be inaccurate because the space between each degree would be different.

2. Would your scale be more accurate if the distance between marks was only half as great? Explain.

Yes. You would be able to measure half-degree variations in temperature, as compared with the first scale.

3. Did any of the beakers of water on the teacher's table cause the mercury (or alcohol) to move above or below your marks? How would you extend your scale to measure these temperatures?

   Yes. To extend the scale upward, add more degrees and (positive) numbers. To extend the scale downward, add more degrees and negative numbers.

4. If you told somebody that the temperature outside was 3251.3°M, what do you think he or she would say? What advantages are there in using thermometers with a scale that everyone agrees upon?

   Variable. If each person used a different temperature scale, it would be difficult for people to exchange information about the warmth or coldness of an object or substance.

Before you continue, read "You can make a temperature measurer" and "Somebody else's scale," pages 328–333 in your text.

Name ______________________

Date ____________ Class ____________

PROBLEM D: ***How do some different substances respond to temperature change?***

Materials:
- 2 Beakers
- 2 Thermometers
- 2 Strips liquid crystal film
- Water
- Ice
- Alcohol burner

Use liquid crystal films that respond to *different* temperature ranges. One strip should be within body-temperature range, e.g., 30°C to 36°C. The other strip should be above body-temperature range, e.g., 45°C to 49°C.

Investigating . . .

Lay two strips of what appears to be plastic film on your desk—shiny side up.

Do whatever you think is necessary (without destroying the material) to determine how both strips are similar and how they are different. Be sure to record what you did to each strip.

Provide students with a beaker of hot water and a beaker of cold water. Some students may decide to dip the liquid crystal film in these beakers to see what happens.

Observing . . .

Variable.

Heat from the fingers will cause one liquid crystal strip to change color. The other strip will remain unchanged.

If dropped in hot water, both strips will change color.

In each case, the color change will be progressive, e.g., from black to red to yellow to green to blue—as the temperature increases.

Interpreting . . .

The material you have been working with is *liquid crystal thermal film*. Based on your observations, what might this material be used for?

Possible answer: liquid crystal could be used as a thermometer to indicate differences in body surface temperature (or differences in water temperature).

YOUR TURN: ***How can you tell temperature differences on the surface of an object?***

Try to find out how heat travels through a glass slide, a strip of metal, and a strip of wood. Use liquid crystal film in your experiment. Describe what you plan to do. State your hypothesis. Then describe your results.

Now read "An unusual thermometer you can use," pages 346–347 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Explain why you cannot measure the temperature of something accurately by touching it.
2. Decide if there has been a temperature change by looking for an expansion or contraction in some material.
3. Make a scale that can be used to measure temperature change.
4. Use liquid crystal thermal film to find differences in the surface temperature of an object or substance.

Name ____________________

Date __________ Class __________

CHAPTER 14: SUPPLYING HEAT

BEFORE YOU BEGIN PROBLEM A . . .

Read "Supplying Heat," page 348 in your text.

Then place three nickels and three glass marbles in a beaker of boiling water. Leave them there until the water starts to boil again.

In the meantime, pour about 50 ml of cold water into each of 3 beakers. Measure the temperature of the water in each beaker. Try to warm the cold water in the three beakers in each of the following ways:

Remove the nickels from the boiling water with tongs. Carefully put the nickels into the first beaker.

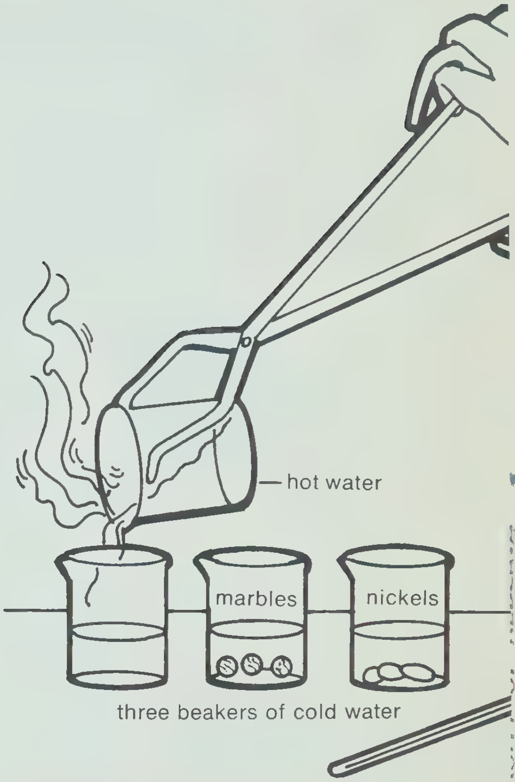
Remove the glass marbles from the boiling water in the same way. Carefully put the marbles into the second beaker.

Then stop heating the hot water. After the water stops boiling, pour about 15 ml of it into the third beaker.

Note any rise in temperature in each beaker. Now think about these questions:

—When the water in your bath is too cool, how do you raise its temperature?

—Is there a way to measure how much heat you have supplied to warm the water?


hot water
marbles
nickels
three beakers of cold water

Styrofoam cups work well in this section. They can be used in place of the three small beakers. Use of the Styrofoam cups will alleviate the problems of glass breakage. However, remind students to keep the cups away from an open flame.

PROBLEM A: ***How are the temperatures of different masses of water affected when they receive the same amount of heat?***

Materials:

- 1 Graduate cylinder
- 1 Beaker, 250 ml
- 3 Test tubes
- 1 Clock
- 1 Test-tube holder
- 1 Thermometer, –10°C to 110°C
- 1 Asbestos pad to fit ring
- 1 Ring stand
- 1 Ring with clamp
- Alcohol burner
- Water

The test tubes should be 150 to 175 mm long and have an outer diameter of at least 20 mm.

You might want students to use safety glasses during this activity.

Refer students having trouble with measurement of liquid volume to page 255 in the Appendix.

I **Investigating . . .**

1. Put 5-ml of water in your test tube. Measure the water temperature and record it in Table 14•1.

Note: Turn to page 255 to find clues for measuring liquid volume with a graduate cylinder.

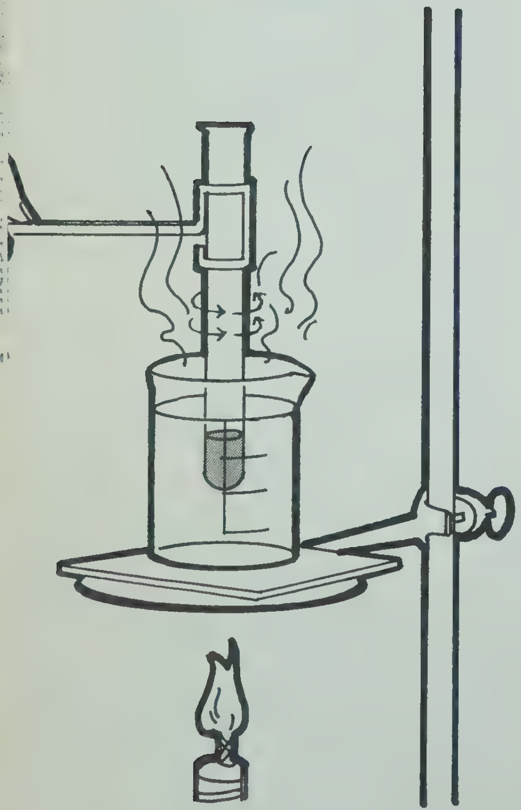
2. Hold the test tube with your test-tube holder.

STOP

KEEP the water in the test tube from boiling. Boiling water will shoot out the top of the tube. You can avoid boiling by moving the test tube around in the beaker of water.

3. Carefully heat the test tube for 30 seconds in a beaker of boiling water.

4. Remove the test tube from the boiling water after 30 seconds. Measure and record the temperature of the water inside the test tube.



Repeat the activity two more times. The second time use 10 ml of water. The third time use 15 ml of water. Record the water temperatures in Table 14•1.

Observing . . .

Table 14•1: Water heated for 30 seconds

Volume of water	Starting temperature	Final temperature	Change in temp. in °C
5 ml	Variable	Variable	As the volume of water increases, the change in water temp. decreases.
10 ml			
15 ml			

Name ____________________

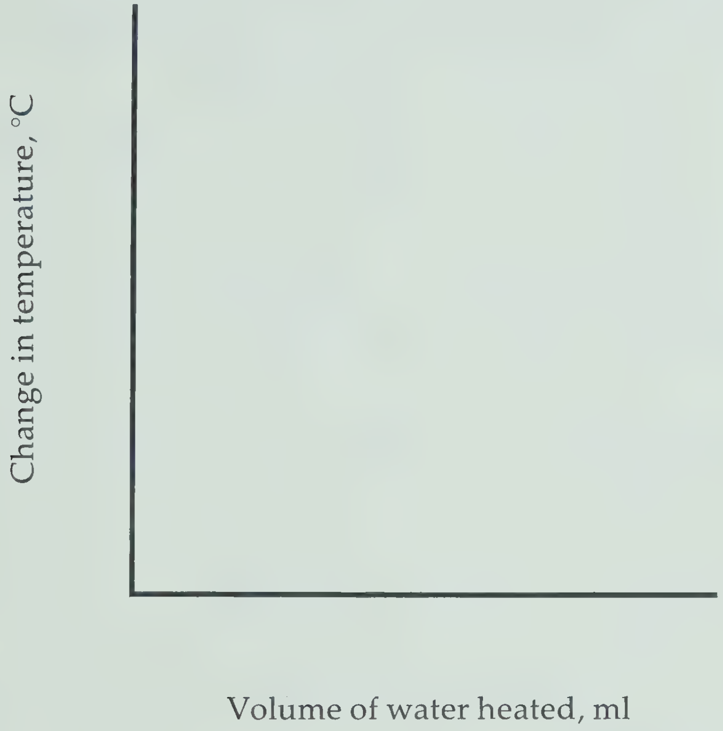
Date __________ Class __________

Interpreting . . .

Plot the data from Table 14·1 on a line graph.

Note: Turn to page 247 to find clues for using line graphs.

It may be helpful to spend some time reviewing graphing. Refer students to page 247 in the Appendix for help in plotting line and bar graphs.



II Investigating . . .

Predict what the final temperature of the three masses of water (Table 14·2) would be if you heated them for 60 seconds each. Record your predictions in Table 14·2. Now heat the water and compare your results with your predictions.

Observing . . .

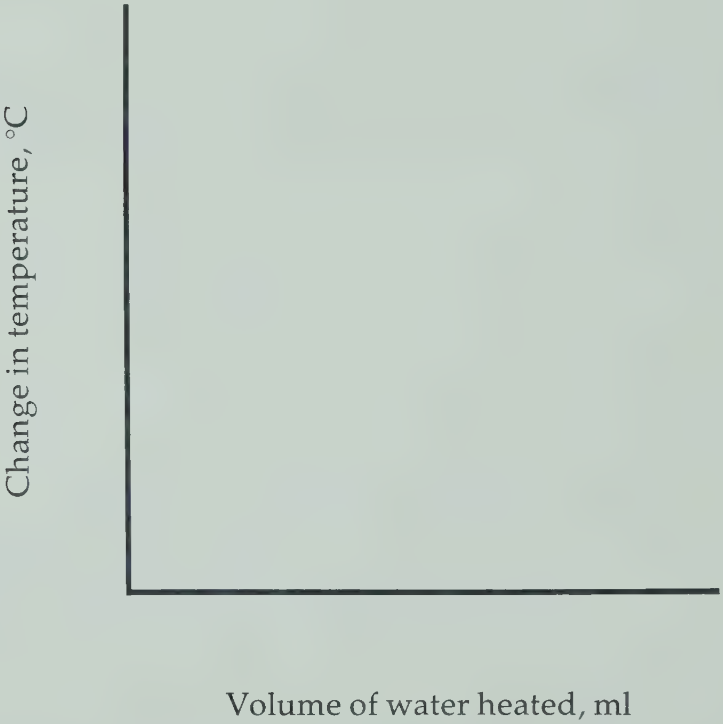
Table 14·2: Water heated for 60 seconds

Volume of water	Change in temperature, °C	
	prediction	actual
5 ml	Variable	Variable
10 ml		
15 ml		

Interpreting . . .

Plot the data from Tables 14·1 and 14·2 on a bar graph. Use a striped bar for the water heated 60 seconds and a plain bar for the water heated 30 seconds.

Note: Turn to page 247 to find clues for making bar graphs.



Tying ideas together:

Do you think a large glass full of cold soft drink or the same glass half full of cold soft drink would come to room temperature more quickly? Use what you have observed to explain your answer.

The heat from the room would heat the *smaller* volume of drink to room temperature more quickly. It takes less time for a smaller volume of water to be heated to a given temperature than a larger volume of water (if the heat source is constant).

Before you continue, read "A balance of temperatures," pages 349–351 in your text.

Name ______________________

Date __________ Class __________

PROBLEM B: ***How much heat can hot water supply to cool water?***

Materials:
2 Beakers, 250 ml
1 Thermometer
4 Styrofoam cups
1 Graduate cylinder, 100 ml
1 Stirring rod
1 Pair beaker tongs
1 Ring stand
1 Ring with clamp
1 Asbestos pad
Aluminum foil
Alcohol burner
Water

Double Styrofoam cups work very well in place of calorimeters. You can get 8-oz or 9-oz Styrofoam cups in packages of 50 at your local grocery or discount store.

Investigating . . .

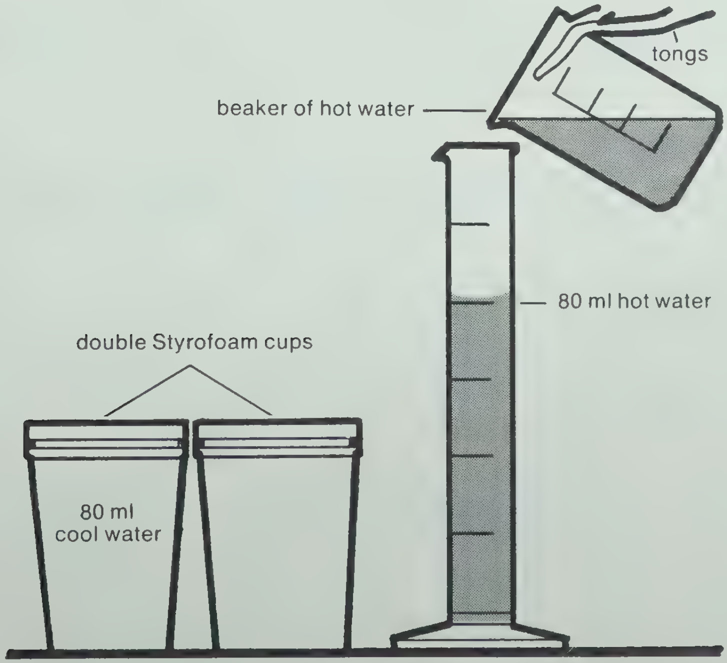
1. Fill a 250-ml beaker with cool water. Set it aside.

2. Fill another 250-ml beaker with hot water. Place the beaker of hot water on your ring stand. Begin heating the hot water. (See page 167 for the setup.)

KEEP Styrofoam cups away from your alcohol burner. Styrofoam catches fire easily. Handle the beaker of hot water with beaker tongs.

STOP

3. Put one Styrofoam cup inside another. Pour 80 ml of the cool water into the double cup. (80 ml of water = 80 gm of water.)



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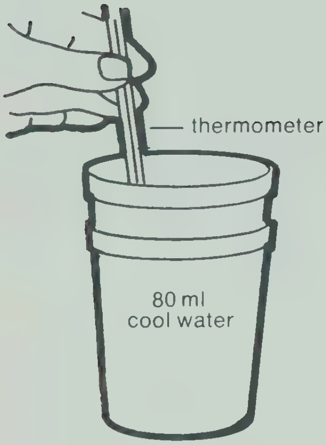
4. Assemble another double Styrofoam cup. Add 80 ml of the hot water to the second double cup. ❶



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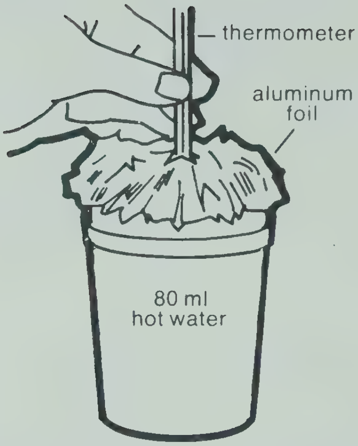

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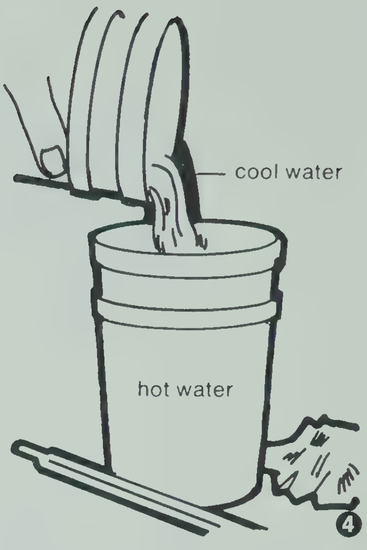


❹

5. Quickly cover the cup with aluminum foil. (Continue heating the hot water left in the beaker. You will use it in the next trial.)

6. Measure the temperature of the cool water in the Styrofoam cups. ❷ Record it in Table 14•3. Poke your thermometer through the aluminum foil. Measure the temperature of the hot water. ❸ Record it in the same table.

7. Uncover the cup of hot water. Quickly pour the cool water into it. ❹ Stir the water. Then find and record its temperature.

Empty and dry both cups. Repeat the activity, using 80 ml of cool water and 40 ml of hot water (Table 14•4).

When the masses of hot water and cold water are mixed, the water will reach equilibrium temperature. This will be halfway between the starting temperatures when equal masses of water are mixed. When unequal masses of water are mixed, the equilibrium temperature will be closer to that of the larger mass of water.

Observing . . .

Table 14•3

	Original temperature	Temperature after mixing (160 gm of water)	Change in temperature
Cool water (80 gm)	Variable	Variable	Variable
Hot water (80 gm)	Variable	Variable	Variable

Name ______________________

Date __________ Class __________

Table 14·4

	Original temperature	Temperature after mixing (120 gm of water)	Change in temperature
Cool water (80 gm)	Variable	Variable	Variable
Hot water (40 gm)	Variable	Variable	Variable

Interpreting . . .

The temperature of the cold water rises because the hot water supplies heat to the cold water. A unit of heat you can use to determine the amount of heat supplied to or supplied by water is the *calorie*. One calorie is the amount of heat needed to raise the temperature of 1 gm of water 1°C.

This activity might require more than an average amount of teacher input because some students might find the calculations difficult.

1. Suppose you heat one gm of water from 80°C to 82°C. (a) How many calories did you supply to the water? ___2___ (b) If the water cools from 82°C to 80°C, how many calories has the water supplied to the air? ___2___

2. Look at the first activity, where you mixed 80 gm of hot water and 80 gm of cool water.

   (a) How many calories were supplied to each gram of cool water?

   The same amount as shown in Table 14·3 under the column titled "Change in temperature" of cool water.

   (b) How many calories did each gram of hot water supply?

   The same amount as shown in Table 14·3 under the column titled "Change in temperature" of hot water.

3. On Table 14·5 below, fill in the column marked "Change in water temperature in °C" with your data. Then calculate the calories supplied by the hot water and gained by the cool water.

Table 14·5

Mass of water in grams	×	1 cal. per gram per 1°C	×	Change in water tempera-ture in °C	=	calories supplied by hot water	calories supplied to cold water
80 (cold)	×	1	×	Variable	=	xxxxxx	Variable
80 (hot)	×	1	×		=		xxxxxx
80 (cold)	×	1	×	Variable	=	xxxxxx	Variable
40 (hot)	×	1	×		=		xxxxxx

4. What have you learned about supplying heat by mixing masses of water when they are at different temperatures? State your answer as a generalization.

When masses of hot and cool water are mixed, the hot water will become cooler and the cool water will become warmer, until both masses of water are at the same temperature.

Before you continue, read "How much heat was supplied?" pages 352–353 in your text.

Name ______________________

Date __________ Class __________

PROBLEM C: *Do all metals supply the same amount of heat?*

Materials:
- 1 Beaker, 600 ml
- 2 Plastic bags
- 4 Styrofoam cups
- 1 Balance and masses
- 1 Ring stand
- 1 Ring with clamp
- 2 Kinds of metal shot
- 1 Graduate cylinder, 100 ml
- 2 Twist ties for plastic bags
- 1 Asbestos pad
- 1 Pair of tongs
- 1 Scissors
- 1 Glass stirrer
- 1 Thermometer
- Alcohol burner
- Water
- Clock

Investigating . . .

1. Fill a large beaker with water. Put it over your alcohol burner.

2. Get two kinds of metal shot. Use your balance to weigh out 80 gm of each.

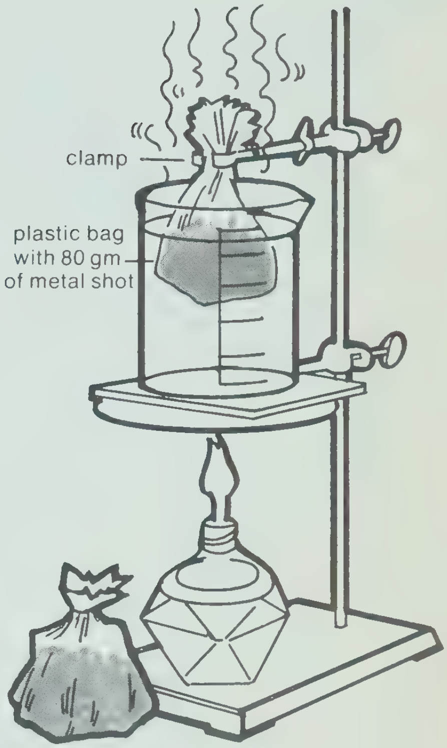
Note: Turn to page 253 to find clues for measuring mass with an equal-arm balance.

3. Put each kind of shot in a plastic bag. Force as much air out of the bags as you can. Then close the bags with twist ties.

4. Put one bag in the heating water. Use a ring stand to clamp the bag in place. Be sure the bag does not touch the bottom of the beaker. ❶

5. Now make two double Styrofoam cups by placing one cup inside another. Pour 80 ml (80 gm) of cool water into each cup.

6. When the water in your beaker boils, measure the temperature of the cool water in one of the double cups. Record it in Table 14·6.



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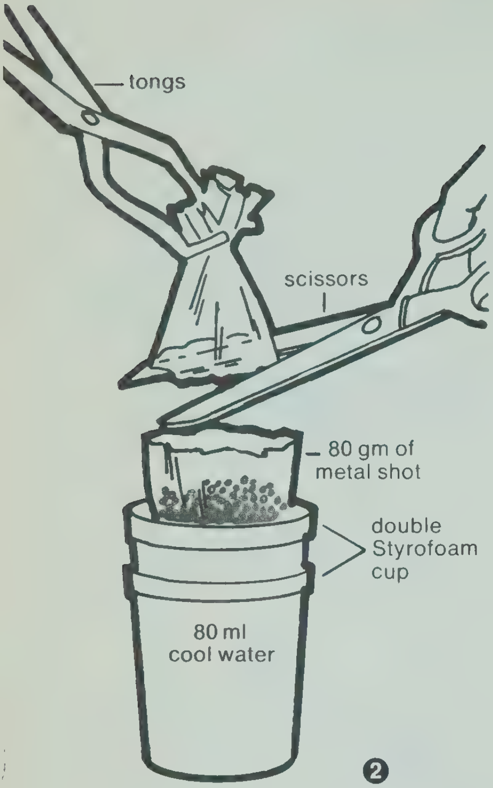
The heat capacity of some common metal shot is as follows:
Aluminum—0.22 cal/gm/°C
Iron—0.11 cal/gm/°C
Lead—0.03 cal/gm/°C
This problem will give the best results if you use aluminum shot and iron or lead shot. The size of the shot will not noticeably affect your results.

Refer students having trouble with the use of an equal-arm balance to page 253 in the Appendix.

Check to see that the plastic bags of shot are clamped so the shot is hanging in the center of the water bath.

If the shot is allowed to touch the bottom of the beaker, the heat source will heat the shot to more than 100°C. Student results will be inaccurate.

Warn students to hold the shot at arm's length because any hot water dripping from the shot may burn them.



❷

7. Wait three minutes. Use your tongs to remove the bag of shot from the boiling water. Quickly hold the bag over the cup of water and cut it just above the shot. Let the bag and shot fall into the water. ❷

8. Use a glass stirring rod to knock most of the shot out of the bag. Stir the water and shot. Measure the temperature of the water and shot. Record the temperature in Table 14·6.

Repeat the activity, but use the other kind of shot and the other cup of water. Record the temperatures in Table 14·6.

Observing . . .

A. Table 14·6

	Water temperature, °C			Mass in grams		Metal temperature, °C		
	at first	final	change	water	metal	at first	final	change
Shot 1		Variable		80	80	100	Variable	
Shot 2				80	80	100		

B. In this activity, did the 80 gm of shot at 100°C cause as big a temperature change as the 80 gm of water in the last activity?

No

Interpreting . . .

1. Look at the results of the last activity (page 178). When you added 80 gm of water at 100°C to 80 gm of cool water, how much did the final temperature change?

Variable

2. Fill in Table 14·7 with your information from Table 14·6.

Name ______________________

Date __________ Class __________

Table 14·7

Kind of metal	Mass of water in grams	×	1 calorie per gram per 1°C	×	Change in temp. of water, °C	=	calories supplied by 80 gm of the metal
	80	×	1	×	Variable	=	Variable
	80	×	1	×		=	

3. Use the information in Tables 14·6 and 14·7 to calculate the calories supplied to the water by 1 gm of each kind of shot.

$$\frac{\text{calories supplied to water by 80 gm of metal shot}}{80 \text{ gm}} = \text{calories supplied to water by 1 gm of that kind of shot}$$

4. Do you think that the amount of heat supplied by each gm of a metal might be used to identify that metal? Give your reasoning.

Yes. Each kind of metal supplies a different number of calories to the water, even though the mass of the two metals is the same.

5. What errors in the experiment might affect your measurement of the shot's ability to supply heat?

Possible answers:

a) Loss of heat to air, instead of to water.

b) Incomplete heating of metal shot or overheating metal shot.

c) Inaccurate measurements of temperature or mass of shot.

d) Inaccurate calculations.

YOUR TURN: *Does steel, brass, or aluminum supply the most heat?*

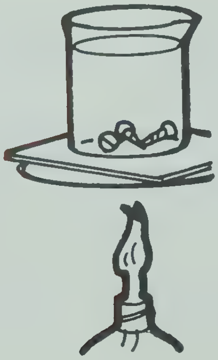
If students have trouble with the measurements or calculations in the previous activity, this activity can be substituted. It requires observation only.

Different kinds of metal washers or metal ball bearings can be substituted for the screws.

In Problem C, you figured out that different metals hold different amounts of heat. They have different *heat capacities*. Here's an easy way to observe the different heat capacities of metals, without doing any figuring:

The metal with the lowest heat capacity will sink the least in the paraffin since it supplies the least heat to melt the paraffin.

Compare the heat capacities of steel, brass, and aluminum screws. Drop three large screws of the *same size* into a beaker of boiling water. Let the screws boil for about 5 minutes. ❶ Boiling raises the temperature of each screw to 100°C. Now, quickly remove the screws with tongs and dry them with a paper towel. Place the screws on a block of paraffin. ❷



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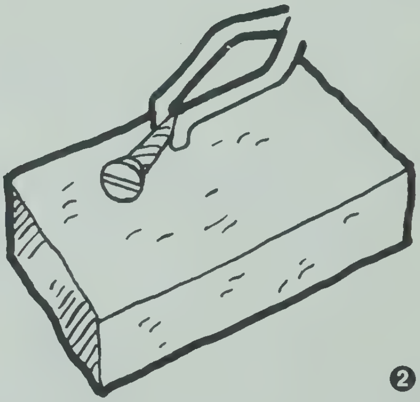


❷

Which metal melts the least paraffin and sinks least? Which metal melts the most paraffin and sinks deepest? Which metal holds the most heat? Why do you think so?

Now read "Supplying heat with hot metal" and "Heat capacity," pages 358–362 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Calculate the amount of heat supplied to cold water by hot water, when you know the mass of the water and its change in temperature.
2. Calculate the amount of heat supplied to cold water by 1 gm of metal, when you know the mass and change in temperature of the water and the metal.

Name ______________________

Date __________ Class __________

CHAPTER 15:
BOILING WATER AND MELTING ICE

BEFORE YOU BEGIN PROBLEM A . . .

Read "Boiling Water and Melting Ice," page 374 in your text.

Then take a strip of liquid crystal film. The temperature range at which this film will change colors is below room temperature. To prove this, hold the film in your hands and note that there is no color change. Then take a piece of metal out of a beaker of ice water. Dry the metal and hold the film against it. Note any color change.

Use liquid crystal thermal film that responds to temperature changes below room temperature (19°C to 25°C). Help students understand that a change in the color of the thermal film indicates a reduction of temperature. The change in temperature is due to evaporation.

Warm the liquid crystal film in your hands. Wet the center of the dull side of the film with two or three drops of lukewarm water. Note any color change. Now think about these questions:

—Why does sweating make you feel cooler?

—Why is it cooler near a frozen lake or stream after the ice begins to melt?

PROBLEM A: ***What happens when you supply heat to melting ice?***

Materials:

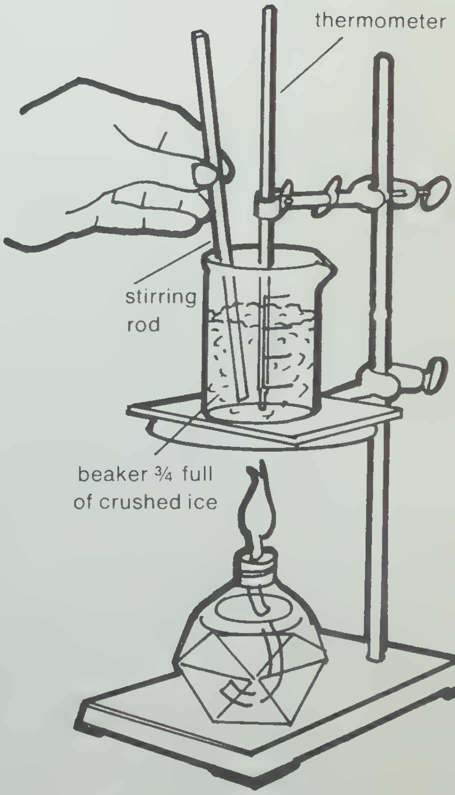
- 1 Stirring rod
- 1 Beaker, 250 ml
- 1 Thermometer
- 1 Clock
- 1 Clamp
- 1 Ring stand
- 1 Ring with clamp
- 1 Asbestos pad
- Water
- Crushed ice
- Alcohol burner

Investigating . . .

1. Fill your beaker 3/4 full of crushed ice. Put it on the ring stand as shown.

2. Push a thermometer gently into the beaker so that it is surrounded by crushed ice. Clamp your thermometer in place so that it will not hit the bottom of the beaker as the ice melts.

3. Place an alcohol burner under the beaker. Stir gently as the ice begins to melt.



Show the students they can stir the contents of the beaker without harming the thermometer. Demonstrate how to move the stirring rod slowly back and forth in the ice and at the *side* of the beaker.

The temperature of the water in the beaker will begin to rise before all the ice melts.

4. Measure the temperature every 30 seconds. Record it in Table 15•1. Keep stirring the mixture of ice and water as the ice melts.

5. Record your temperature readings for three minutes after the ice has melted.

Observing . . .

Table 15•1

Time, minutes	Temperature, °C	Time, minutes	Temperature, °C	Time, minutes	Temperature, °C
0		8			
0.5		8.5			
1		9			
1.5		9.5			
2		10			
2.5		10.5			
3		11			
3.5		11.5			
4		12			
4.5		12.5			
5		13			
5.5		13.5			
6		14			
6.5		14.5			
7		15			
7.5		15.5			

Name ____________________

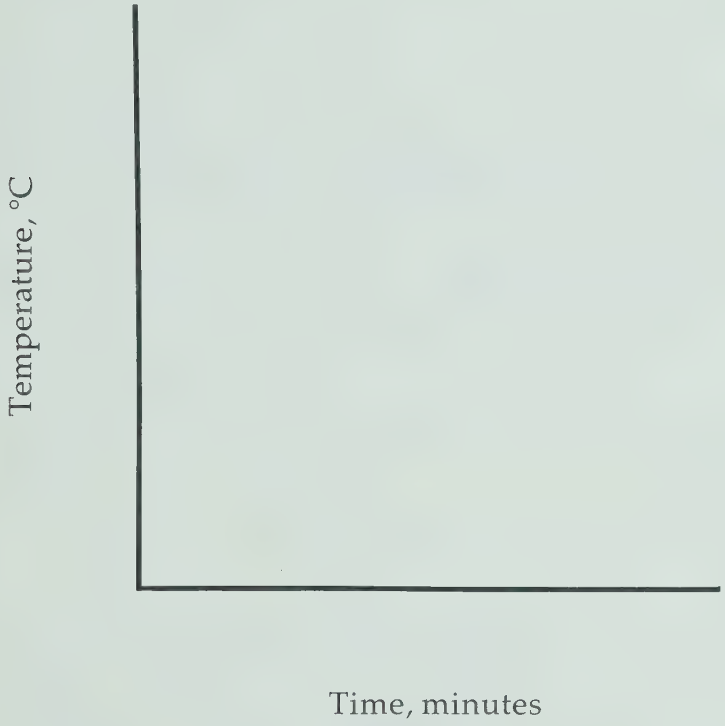
Date __________ Class __________

Interpreting . . .

Refer students having trouble with graphing to page 247 in the Appendix.

Plot the data in Table 15·1 on a line graph. Circle the point on the graph at which all the ice melted.

Note: Turn to page 247 to find clues for making a line graph.



Use your graph to answer the following questions:

1. Describe the shape of the curve up to the point at which the ice melts.

   It is almost flat.

2. Describe the shape of the curve beyond the point at which the ice melts.

   It rises sharply.

3. What does the change in the shape of the curve indicate?

   All the heat being supplied to the water is now causing the rise in water temperature.

4. What do you think happened to the heat that was supplied to the ice during the time there was no change in temperature?

   Variable. Could include the following: It melted the ice. It was heat of fusion.

5. State a generalization about what happens when heat is supplied to melt ice.

   The temperature of the ice water remains unchanged (about 0°C) until almost all the ice melts. After nearly all the ice melts (about 0°C), the temperature of the water begins to rise sharply.

Before you continue, read "Melting ice," pages 375–378 in your text.

Name ______________________

Date __________ Class __________

PROBLEM B: ***What happens when you supply heat to boiling water?***

Materials:		
	1 Beaker, 250-ml	1 Asbestos pad
	1 Marking pen	1 Clamp
	1 Thermometer	Alcohol burner
	1 Ring stand	Clock
	1 Ring and clamp	

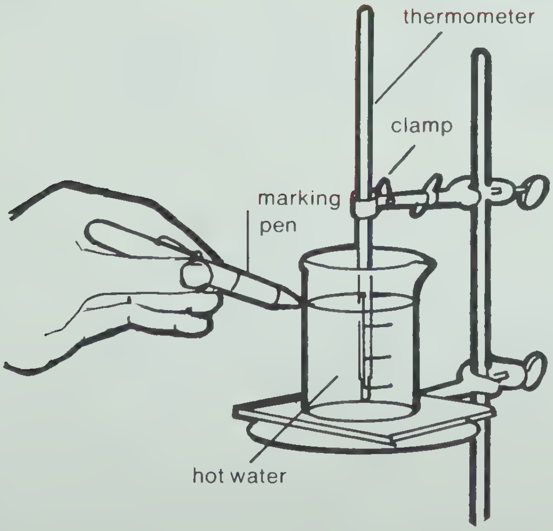
Investigating . . .

1. Fill your beaker two-thirds full of hot water. Mark the level of water in the beaker.

2. Put the beaker on the ring stand. Place the thermometer in the water. Hold the thermometer in place with the clamp on the ring stand.

Be sure that the thermometer is away from the bottom of the beaker. The thermometer is likely to break if it touches a hot surface.

STOP



3. Place your heat source under the beaker. Take the temperature reading of the water every minute, until the water reaches 100°C. Record the temperature in Table 15•2.

4. Continue to measure temperature of the water every minute for five more minutes. Record the temperature readings in the same table.

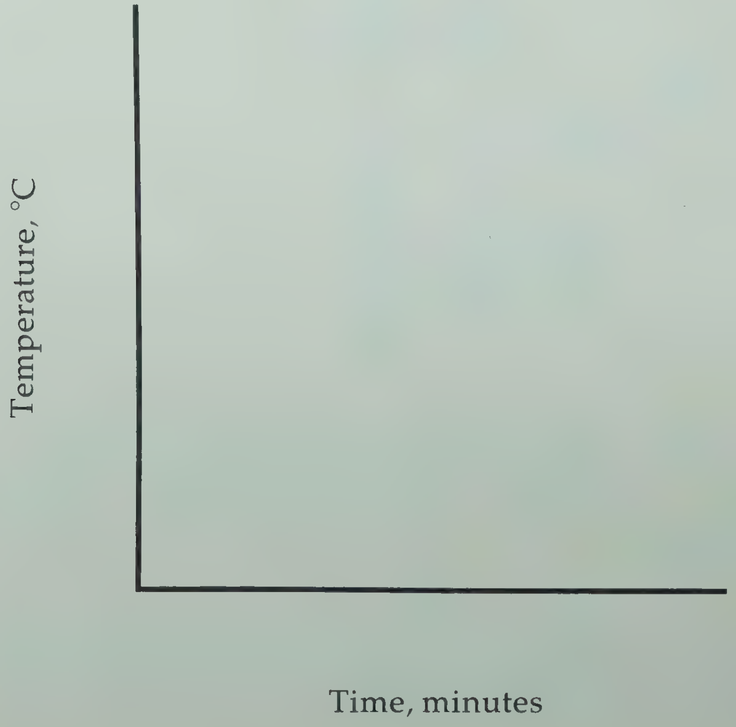
Observing . . .

Table 15·2

Time, minutes	Temperature, °C	Time, minutes	Temperature, °C	Time, minutes	Temperature, °C
0		7		14	
1		8		15	
2		9		16	
3		10		17	
4		11		18	
5		12		19	
6		13		20	

Interpreting . . .

Plot the data in Table 15·2 on a line graph. Circle the point on the graph at which the water boiled.



Name ______________________

Date __________ Class __________

Use your graph to answer the following questions:

1. Describe what happened to the curve before the water began to boil.

   It rose steadily.

2. During the time the water boiled, did the temperature change? Try to explain your observation.

   No. The water temperature rises until the water begins to boil (100°C). Then the temperature remains unchanged. The heat is used to boil the water.

3. What was the heat energy used for during the first part of the experiment?

   It was used to increase the temperature of the water.

4. Was there any change in the level of the water in the beaker? Explain your answer.

   Yes. Some of the water boiled away.

Before you continue, read "Boiling water," pages 379–380 in your text.

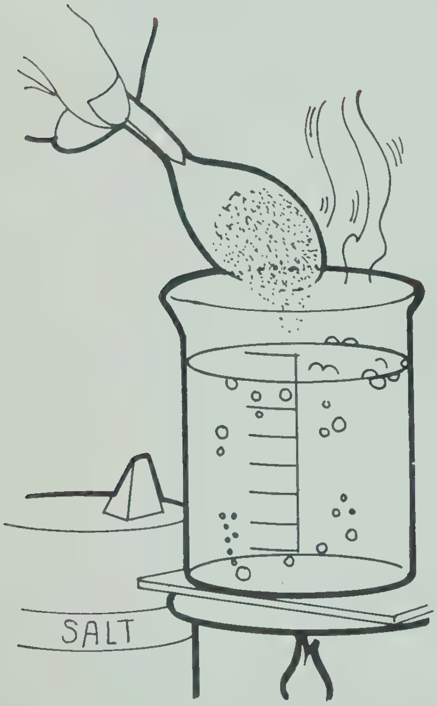
It takes a lot of salt to change the boiling point of water—about 58 grams per liter for a 0.5°C change in temperature.

Boiling the water more rapidly will not cause a change in the temperature reading.

YOUR TURN: ***Can you change the boiling point of water?***

Put a 250-ml beaker of water over a heat source. Heat the water until it boils. Take a temperature reading of the boiling water. Record the reading. Now boil the water more rapidly. Read the thermometer again. Is there any change? Try to explain your observation.

Add a tablespoon of salt to a beaker of water. When the water boils, read the thermometer. Is the boiling point of water higher or lower after salt is added? Add 3 more tablespoons of salt, one at a time. Measure the water temperature after each addition. Is there any change in the boiling point of the water?



Name ____________________

Date __________ Class __________

PROBLEM C: ***How does temperature affect the movement of liquids?***

Materials: 2 Beakers, 250 ml
1 Eye dropper
Food coloring

Investigating . . .

Find out how temperature affects the rate at which two liquids mix.

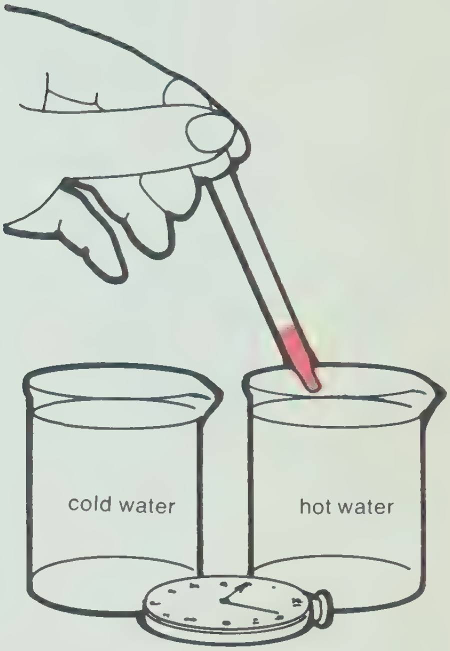
1. Fill one beaker with cold water. Fill the other beaker with hot water. Measure the temperature of the water in each beaker. Record the temperatures in Table 15•3.

2. Let each beaker stand for 5 minutes.

3. Carefully put a drop of food coloring or ink on top of the water in each beaker. Be careful not to move the water. Observe the speed with which the coloring spreads. Describe what you see in Table 15•3.

The spread of the coloring through the water is called *diffusion.*

4. Record how long it takes the coloring to diffuse in each beaker (Table 15•3). If the coloring has not completely diffused in each beaker after 15 minutes, describe how it looks at that time.



This experiment will not work unless the water in the beakers is absolutely still when the drop of food coloring is placed on it.

Observing . . .

Table 15•3

Water temperature	Time	Spread of color
Beaker #1 Variable		Color will spread more rapidly in the beaker of hot water.
Beaker #2		

Interpreting . . .

1. Describe how temperature affects the rate at which one liquid diffuses into another.

   An increase in temperature increases the rate at which one liquid diffuses into another.

2. Assume that air acts like a liquid. Would you expect an odor of garlic to spread faster in a cold room or a warm room? Explain.

   A warm room. At a higher temperature the garlic in the air would spread or diffuse more quickly.

3. Give some examples of diffusion you have observed.

   Variable

Now read "Comparing the states of matter" and "Supplying heat without change of state," pages 383–387 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Predict how the temperature of a given amount of ice will be affected when heat is supplied to melt that ice.
2. Predict how the temperature of a given amount of water will be affected when heat is supplied to boil that water.
3. Given the temperature of two cups of water, predict in which cup a liquid will diffuse more rapidly.

Name ____________________

Date ________ Class ________

CHAPTER 16: VARIETY IS THE SPICE OF LIFE

Turn to page 260 in the Teacher's Appendix to find the quantities and substances needed to prepare the samples for this activity.

BEFORE YOU BEGIN PROBLEM A . . .

Read "Chemistry" and "Variety Is the Spice of Life," pages 396–400 in your text.

Then look carefully at the samples your teacher has placed in the classroom for you.

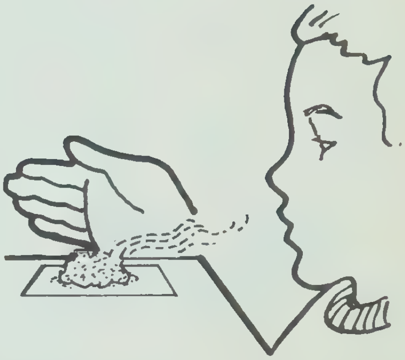
DO NOT TASTE ANY SAMPLES. Some of them are POISONOUS. Nothing should ever be tasted in the laboratory.

Look at each sample with and without a magnifying glass. Use your hand to fan some air from above each sample toward your nose. Now think about these questions:

—Do you think all the powders of one color are the same substance?

—Do you think all the shirts of one color in your classroom are made of the same material?

—If you were given a pile of sand mixed with sugar, how would you separate the two?



PROBLEM A: ***What are some methods you could use to tell whether substances are alike or different?***

Materials:
4 Beakers, 150 ml
4 Evaporating dishes
1 Teaspoon
1 Magnifying glass
1 Ring stand
1 Pair of safety glasses
1 Two-hole rubber stopper, #6
2 Flashlight batteries, 1.5 volts, in holders
1 Bulb, 3.75 volts, in holder
3 Wires with clips at each end
7 Unidentified samples (4 samples per team)
1 Clamp
1 Porcelain spoon
2 Iron nails, #20
Alcohol burner
Distilled water

To obtain the best results use distilled water where suggested.

Students who wear shatter-proof glasses do not need to wear safety glasses.

I **Investigating . . .**

Break into teams of two for this activity.

1. Pick four different samples from any of the seven groups of samples that your teacher has placed in the classroom for you. Take your samples back to the lab table.

2. Look at these samples again with and without a magnifying glass. Describe what you see (Table 16•1).

Observing . . .

Table 16•1

Sample #	Appearance
1, 2, and 3	Blue or bluish green powders
4, 5, 6, 7, and 8	White powders

Interpreting . . .

1. Do you think it might be possible to tell some different substances apart just by looking at them? Use your observations to support your answer.

   Yes. The colors of some of the powders are different. You might use color to tell different substances apart.

2. Is it possible that two samples of the *same* substance can look different? Give examples.

   Yes. Variable. Might include: Two pieces of colored chalk look different, but both are chalk. A powdered substance can look different from crystals of the same substance. Granular sugar looks different from powdered sugar, but both substances are sugar.

Before you continue, read "A set of properties," pages 401–404 in your text.

Name ____________________

Date __________ Class __________

II **Investigating . . .**

Try to learn more about the four samples you chose earlier.

1. Put on your safety glasses.

2. Get four beakers and four evaporating dishes. Label the beakers and dishes with the numbers of your samples. Then put 100 ml of distilled water into each of your beakers.

Note: Turn to page 255 to find clues for measuring liquid volume.

Refer students having trouble with the use of the graduate cylinder to page 255 in the Appendix.

The alligator clips rest on the edge of the beaker, keeping the stopper and nails from dropping to the bottom of the beaker.

3. Stir a level teaspoonful of each sample into the beaker labeled with its number. Be sure to rinse and dry the spoon after you measure out each sample.

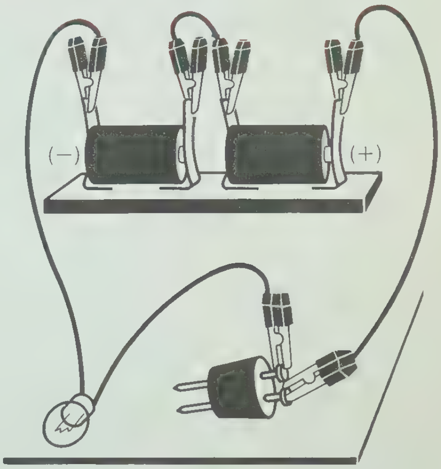
4. Let the mixtures in each beaker stand for about 5 minutes, then stir again. Notice which of the samples dissolved in water. Record your observations in Table 16•2.

Now you're going to make a tool that you can use to find out if any of the solutions conduct an electric current. The tool is called a *conductivity tester*.

5. To make the tool, attach two batteries, a light bulb, a two-hole stopper, and two nails as shown. ❶ The nails will conduct an electric current. Touch them to each other and the bulb will light. Make sure the nails on your conductivity tester are clean and dry.

6. Put the nails into the solution in the first beaker. ❷ If the solution conducts an electric current, the bulb will light up. Record whether or not the first solution sample conducts electricity (Table 16•2).

Repeat the test on the other three solutions. Be sure the nails are clean and dry before each use. Use a beaker filled with distilled water to rinse off the nails. Record your results in the same table.



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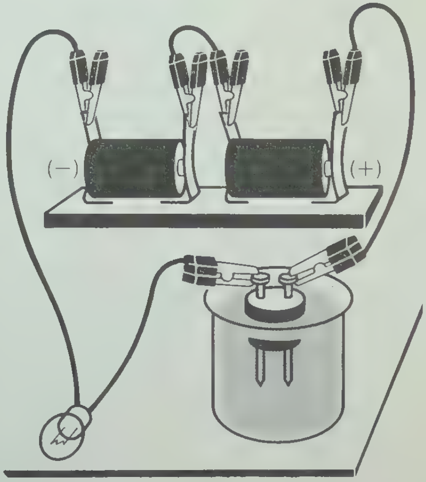

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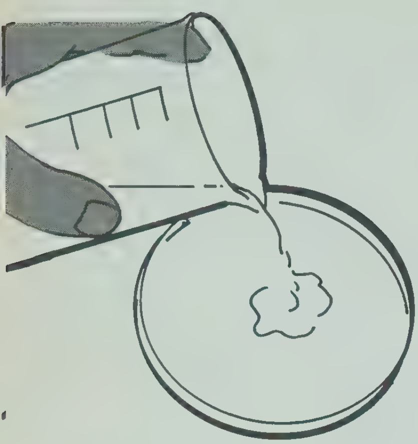


7. Now pour 3 ml of each sample into the evaporating dish labeled with its number. ❸ Set the dishes aside until the next lab period.

❸ It may take more than one night for the crystals to form. Crystals of copper II nitrate will never form. This is an important property of copper II nitrate.

Observing . . .

Table 16·2

Sample #	Does the sample dissolve in water?	Does the sample conduct electricity?
1	Yes	Yes
2	No	No
3	Yes	Yes
4	No	No
5	Yes	Yes
6	Yes	No
7	No	No

Interpreting . . .

1. Now do you think that any two of your samples might be the same substance? Use your observations to support your answer.

   Variable. Will depend on samples student has. Substances #1 and #3 seem to be very similar so far. Substances #4 and #7 also seem to be very similar.

2. How many different substances do you think you might have, so far?

   Variable.

Physical property is defined on page 404 of the assigned reading in the text.

3. Describe three physical properties you have found for each substance.

   Variable. Should include sample numbers and description of the color, solubility, and conductivity of each sample.

Name ____________________

Date __________ Class __________

III **Investigating . . .**

Use a magnifying glass to examine the substance left in each of your evaporating dishes. Describe what you see (Table 16·3). Draw pictures of the samples if they will help.

Observing . . .

Table 16·3

Sample #	Appearance
	Variable. Will depend on sample. Students should not see crystals
	for samples #1, #2, #4, and #7. Students should see blue crystals
	for sample #3, cubic colorless crystals for sample #5, and
	colorless prism-like crystals for sample #6.

Interpreting . . .

The different shapes you see in some of the evaporating dishes are called *crystals.* How can the shapes of the crystals you see help you decide if two substances are the same or different?

The crystals that did form on the dishes all look a little different. They could be from different substances.

IV Investigating . . .

Find out what happens to each of your samples when it is heated.

1. Put on your safety glasses.

2. Fill a porcelain spoon about half full of one of your samples.

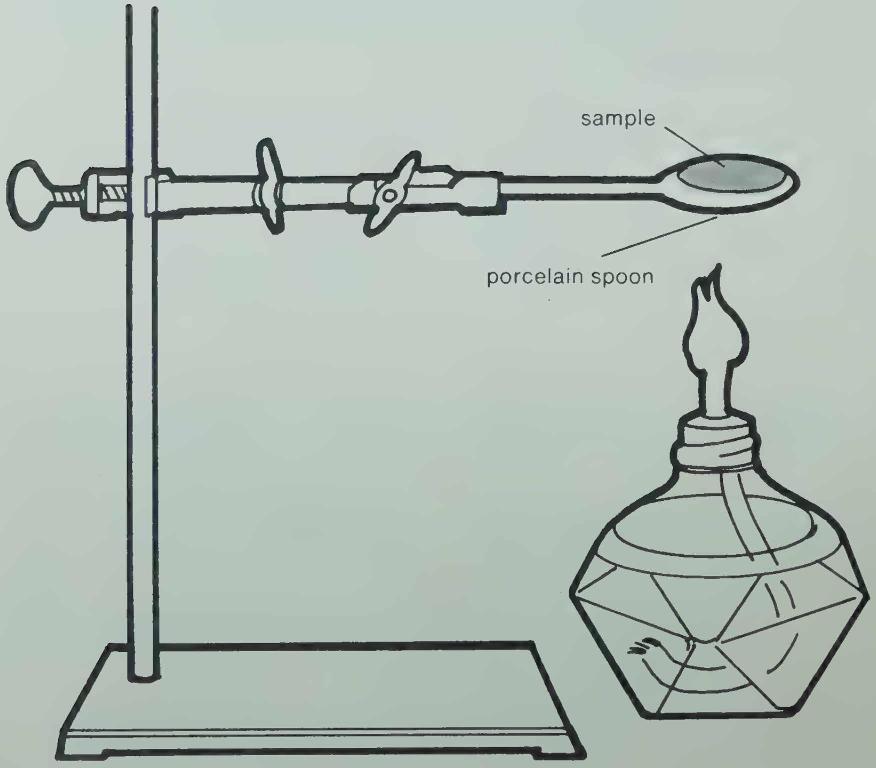
STOP

ALWAYS keep your hands, hair, and clothing away from an open flame.

ALWAYS use tongs to pick up the hot spoon.

3. Set up your alcohol burner and ring stand as shown. Clamp your spoon in place over the burner. Then light your burner.

4. Leave the spoon over the flame until the sample melts, or for about 10 minutes. Turn off your burner. Describe what has happened to the sample (Table 16•4).



Name ______________________

Date __________ Class __________

Clean the spoon and repeat the activity with each of the other three samples. Write all your observations in Table 16·4.

Observing . . .

Table 16·4

Sample #	Observations
	Sample #1 melts. Sample #2 becomes black powder. Sample #3 turns green. Samples #4 and #5 do not change. Samples #6 and #7 melt.

Interpreting . . .

How many different substances do you think you have now? Describe the properties you have found for each of them.

Variable, depending on samples.

Tying ideas together:

When chemists try to determine if substances are the same or different, they want to run as few tests as possible. In what order would you arrange the tests in this problem to find out as quickly as possible if the samples you had were alike or different? Explain your answer.

Order of tests and explanation will vary according to samples student had. For instance, a student who had samples #1, #2, #6, and #7 might say to test solubility and appearance first. That student had two blue samples and two white samples, with one sample of each color soluble in water.

Before you continue, read "Two white powders—alike or different?" and "Identifying the white powders," pages 405–411 in your text.

Name ____________________

Date __________ Class __________

PROBLEM B: ***How can you separate substances in a mixture?***

Materials:
- 1 Funnel
- 2 Beakers, 150 ml
- 1 Ring stand
- 1 Ring with clamp
- 1 Evaporating dish or watch glass
- 1 Pair of safety glasses
- 1 10-gm sample of a mixture (copper II carbonate + copper II sulfate)
- Filter paper
- Distilled water

Turn to page 260 in the Teacher's Appendix to find directions for preparing the copper II carbonate and copper II sulfate mixture.

Demonstrate the use of filter paper and method of filtration for the class.

Investigating . . .

Put on your safety glasses. Then take a sample of the mixture of two substances that your teacher has placed in the classroom for you. Describe the sample in Table 16•5.

Now you are going to try to separate the substances in the mixture by using two different methods:

Method #1:

1. Spread some of the mixture on a sheet of paper.

2. Try to separate the two substances by pushing the particles of one substance away from those of the other substance. Describe what happens when you try to separate substances in the mixture by using this method.

Method #2:

1. Put the mixture into a beaker. Add 100 ml of distilled water to the mixture. Stir the mixture for two or three minutes. Then let the beaker stand for five minutes. Any solids in the beaker that do not dissolve will fall to the bottom.

2. Pour as much of the clear liquid as you can from the first beaker into another clean beaker. ❶

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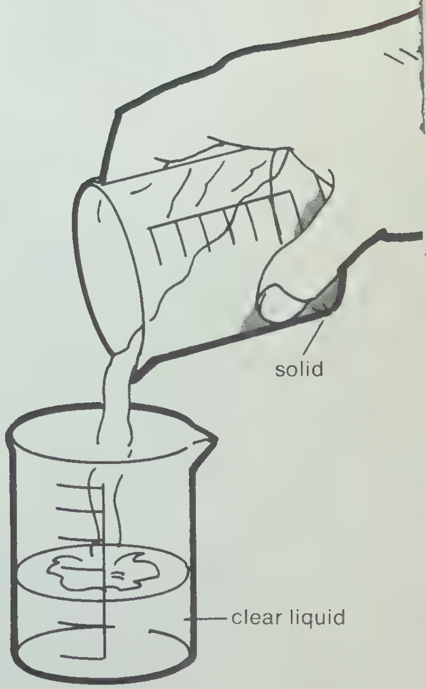
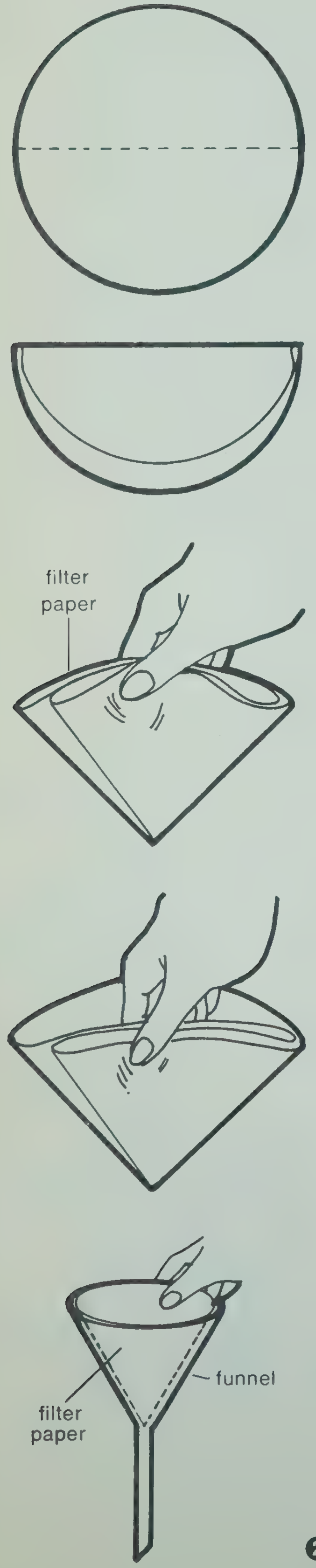


3. Fold a piece of filter paper as shown. Open the filter paper into a cone. Adjust the paper cone so it fits into your funnel. ❷



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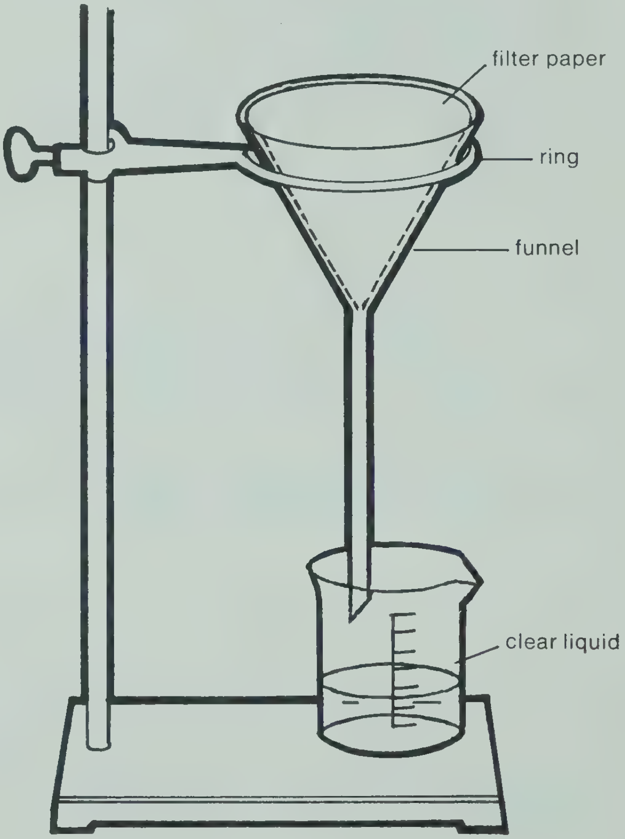
4. Place the funnel in the ring stand as shown. ❸ Put the beaker of clear liquid under the funnel.



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5. Pour the rest of your mixture of solid and liquid into the filter-paper cone. Collect the liquid that drips through the filter paper into the beaker of clear liquid.

6. Rinse the solid left on the filter paper by pouring 5 to 10 ml of distilled water through the filter paper.

7. Pour about 5 ml of the clear solution that dripped into the beaker onto an evaporating dish. Set the dish aside until the next laboratory period.

8. Remove the filter paper from the funnel and set it aside too.

Name ____________________

Date __________ Class __________

Look at the substance on the evaporating dish and the substance on the filter paper during the next laboratory period. Record the color of each sample in Table 16•5. Also record the shape of the crystals and whether or not each sample is soluble in water.

Observing . . .

A. Describe what happened when you tried to separate two substances in a mixture by pushing the particles of each substance apart:

There were so many particles and they were so small that it was impossible to separate the two substances.

B. Table 16•5

Material	Color	Shape of crystals	Soluble in water?
Mixture	Green	Powder	Part of it
Substance 1	Green	Powder	No
Substance 2	Blue	Long clear blue crystals	Yes

Interpreting . . .

1. Could you separate the substances in the mixture by hand? Use your observations to support your answer.

   No. The particles are very small and well mixed.

2. Why do you think you could separate the substances by adding water to the mixture?

   One substance dissolves in water and the other substance does not.

3. Could you always separate two substances in a mixture by adding water? Explain your answer.
   No. If both substances dissolved in water or if neither substance dissolved in water, you could not separate them using this method.

Now read "Pure substances and mixtures of substances" and "Taking apart mixtures," pages 412–418 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Given samples of two unknowns that look alike, use four different tests (solubility, conductivity, crystal formation, and reaction to heat) to tell if they are the same substance.

2. Separate two substances in a mixture, if one is soluble in water, by adding water to the mixture and filtering the solid.

Name ____________________

Date __________ Class __________

CHAPTER 17: CHANGING SUBSTANCES

BEFORE YOU BEGIN PROBLEM A . . .

Read "Changing Substances," page 426 in your text.

Then look at the substances your teacher has placed in the classroom for you. The brown liquid was made by heating sugar. Compare the sample of unheated sugar with the brown liquid. Put 2 or 3 ml of the liquid on an evaporating dish. Be careful! It's hot! Let the evaporating dish and liquid stand overnight. Then check to see if there are sugar crystals on the dish.

Now take a piece of rusted iron. Compare it to the sample of pure iron. Compare the sample of the cupcake or cookie to the unbaked batter. Then think about these questions:

—Is the brown liquid just melted sugar?

—Is the rust still iron?

—What do the brown liquid, rust, and cupcake (or cookie) all have in common?

Place the following items somewhere in the classroom: sugar, sugar heated until it is a brown liquid, iron, rusted iron, a small amount of cake or cookie batter, and a cupcake or a cookie.

Keep the brown liquid in a beaker over a heat source (hot plate) so that the liquid does not harden.

PROBLEM A: *What happens in chemical changes?*

Materials:

1 Eye dropper
1 Balance and masses
6 Test tubes
3 Beakers, 150 ml
1 One-hole stopper
1 Crucible, porcelain
1 Ring stand
1 Clamp
1 Funnel
1 Iron ring with clamp
1 Test-tube rack
1 Pair of safety glasses
2 Iron nails (not galvanized)
1 Glass or plastic tubing, bent in a U

Zinc
Aluminum shot
Copper sulfate
Vinegar (acetic acid)
Household ammonia
Bromthymol blue
Steel wool
Paper
Filter paper
Distilled water
Alcohol burner
Baking soda (sodium bicarbonate)

One 4-oz bottle of 0.04% solution of bromthymol blue indicator will supply five science classes for a year. Bromthymol blue is an acid-base indicator. It is blue in an alkaline solution and yellow in an acidic solution.

Cut and bend the lengths of glass tubing for the class. If you are unfamiliar with techniques for cutting and bending glass, refer to A SOURCEBOOK FOR ELEMENTARY SCIENCE, by Hone, et al. See Teacher's Handbook—professional bibliography.

To avoid accidents, insert the tubing into the stoppers before class. For information on how to safely insert glass tubing into rubber stoppers, turn to page 259 in the Teacher's Appendix.

I **Investigating . . .**

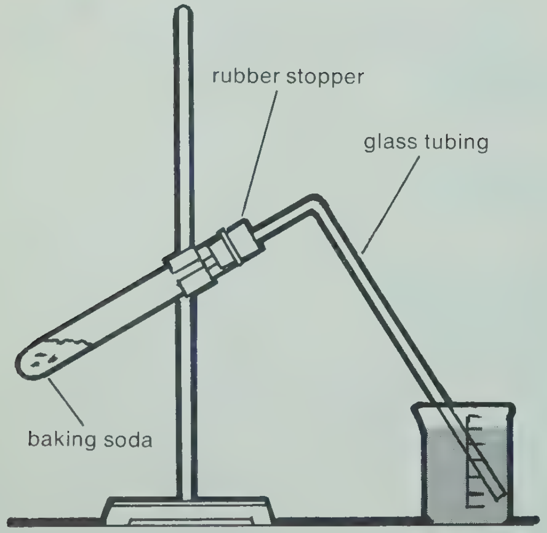
1. Put on your safety glasses.

2. Put 100 ml of distilled water into a beaker. Add 1 drop of household ammonia. Then add 5 drops of the blue liquid (bromthymol blue) from the dropper bottle.

3. Put baking soda (sodium bicarbonate) in a test tube until it is one-quarter full. Put the stopper with glass tubing into the test tube and set up your equipment as shown. ❶ Heat the test tube for ten minutes. ❷

STOP

REMOVE the tubing from the beaker first. Then remove the heat from the test tube. Otherwise the liquid in the beaker will be "pulled" into the hot test tube. The test tube will break.



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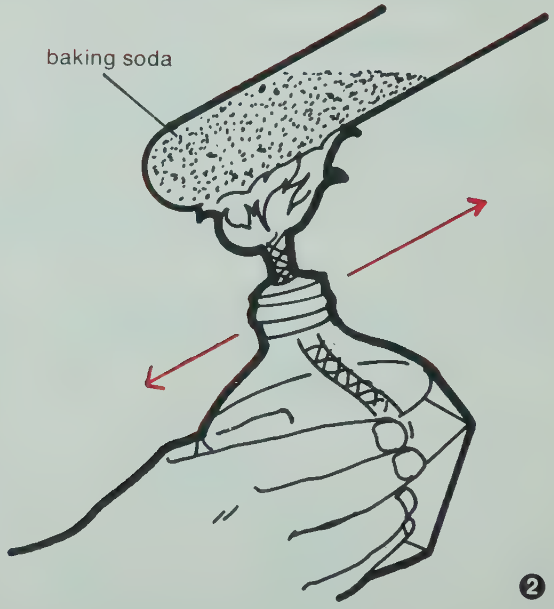

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Record any changes that you see taking place in the test tube and beaker.

Observing . . .

A. Changes in the test tube:

Moisture collects on the side of the tube.

Name ______________________

Date __________ Class __________

B. Changes in the beaker:

When the baking soda is heated, gas bubbles through the blue liquid. The blue liquid turns colorless, then yellow.

Interpreting . . .

1. What evidence do you see that a chemical change took place in this activity?

   A gas bubbled through the blue liquid (solution). The color of the blue liquid (solution) changed.

2. Do you think the same thing would happen if you bubbled steam through the blue liquid in the beaker?

   No. Steam is water vapor. The blue liquid is mostly water. Bubbling more water through the liquid should have no effect.

3. What do you think caused the color of the blue liquid to change?

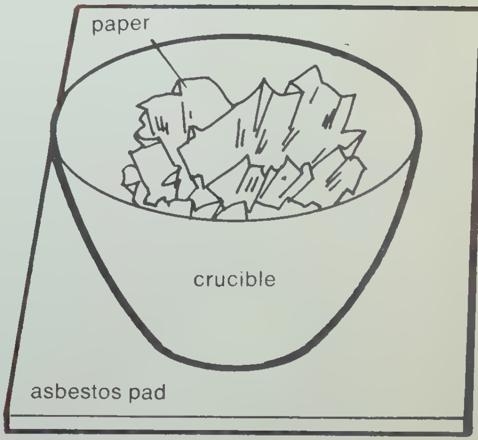
   The gas given off when the baking soda was heated caused the color of the blue liquid (solution) to change.

4. What do you think happened to the baking soda?

   It gave off something (gas) when it was heated.

II **Investigating . . .**

1. Put on your safety glasses.
2. Tear up a piece of paper and look at the shape, size, and color of pieces. Then place the pieces in your crucible. ❶



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STOP

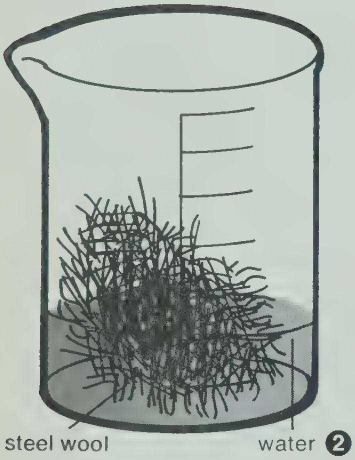
AVOID putting your face over the flames in the crucible. You could be burned.

3. Burn the paper. Examine what is left after the fire is out. Use the space provided to describe what you see.

4. Examine a sample of steel wool carefully. Cut it into two pieces.

5. Put one piece into a beaker containing 25 ml of tap water. ❷ Examine it next class period. Record your observations in the space provided.

6. Place the other piece of steel wool in your crucible. Burn the steel wool. After the fire is out, examine the steel wool carefully. Record your observations.



Observing . . .

A. Describe any changes in the paper when you tore it up.

The paper changed shape and size.

When you burned it.

It turned to ash.

The steel wool may not catch fire unless the strands are pulled apart so that it is airy rather than compact. Warn students to *carefully* pull the strands apart, so that their hands are not cut by the steel wool.

B. What happened to the steel wool when you burned it?

It changed color and texture after burning.

What happened to the steel wool when you left it in water overnight?

It rusted.

Interpreting . . .

1. a) Did you change the paper into a new substance when you tore it up? No

   b) When you burned it? Yes

Name ____________________

Date __________ Class __________

c) Explain your answers.

The torn-up paper could be glued back together. The burned paper could not be put back together. Its color, texture, and other physical properties changed.

2. a) Did you change the steel wool into a new substance when you burned it? Yes

b) When you left it in water overnight? Yes

c) Explain your answers.

It changed texture, color, and other physical properties in both cases.

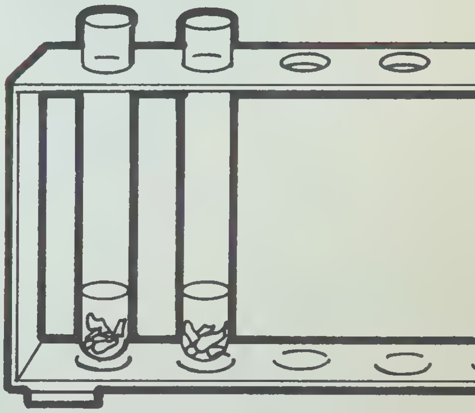
3. What evidence did you see that any chemical changes took place in this activity?

The original substances no longer existed after the paper was burned and after the steel wool was burned and rusted. The new substances had different colors and textures than the original substances.

III Investigating . . .

1. Put on your safety glasses.

2. Put two or three small pieces of zinc into each of two test tubes. Pour enough vinegar into one tube to cover the zinc. Pour an equal amount of ammonia into the other tube. Set both tubes in your test-tube rack. ❶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3. Put an iron nail into each of two other test tubes. Cover the nail in one tube with vinegar. Cover the nail in the other tube with ammonia. Set both tubes in your rack.

4. Put five or six pieces of aluminum shot into each of two test tubes. Cover the shot in one tube with vinegar. Cover the shot in the other tube with ammonia. Set both tubes in your rack.

Record anything that happens in all tubes (Table 17•1).

Observing . . .

Table 17·1

Substances	Changes you observed
Zinc and vinegar	Small bubbles form on zinc
Zinc and ammonia	None
Iron nail and vinegar	Small bubbles form on nail
Iron nail and ammonia	None
Aluminum and vinegar	None
Aluminum and ammonia	Small bubbles form on aluminum.

Interpreting . . .

1. Do you see any evidence that chemical changes might have taken place between the metals and vinegar or ammonia? If so, describe the evidence.

   Yes. Bubbles formed on the zinc, iron nail, and aluminum.

2. Vinegar is a substance that belongs to a chemical group called *acids.* Ammonia belongs to a chemical group called *bases.*

   (a) Which of the metals you used reacted with both the acid and the base?

   None.

   (b) Which of the metals you used reacted with only the acid?

   Zinc and iron

   (c) Which of the metals you used reacted with only the base?

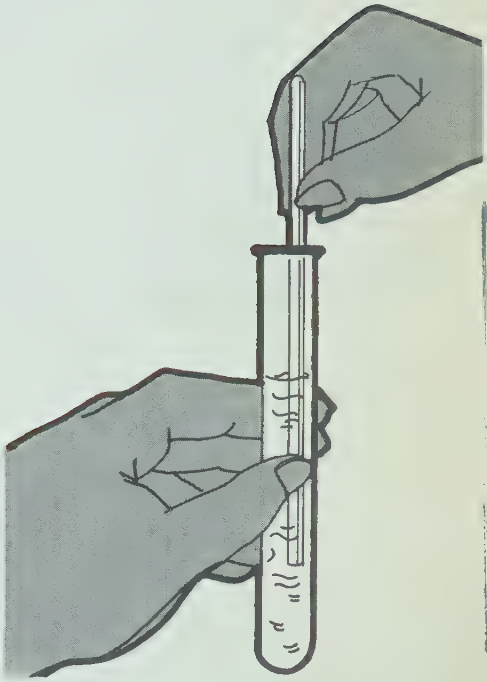
   Aluminum

Name ________________________

Date __________ Class __________

3. The *chemical properties* of a substance are all the chemical reactions in which that substance takes part. Name a chemical property you have discovered for each of the metals used in this activity.

   A chemical property of zinc is that it reacts with acids. A chemical property of iron is that it reacts with acids. A chemical property of aluminum is that it reacts with bases.



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IV Investigating . . .

1. Put on your safety glasses.

2. Place about 2 gm of baking soda in a test tube. Record the color of the baking soda (Table 17·2).

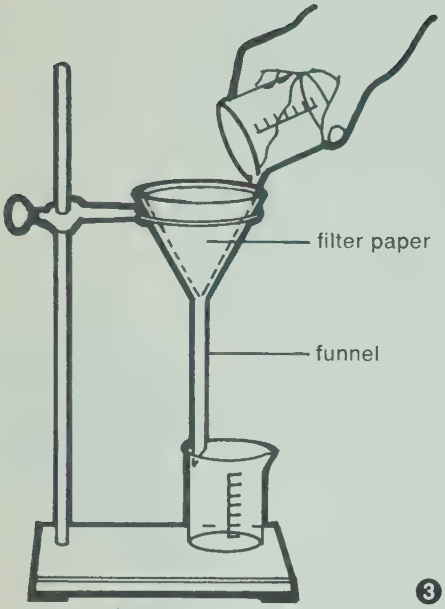
Note: Turn to page 253 to find clues for measuring mass with an equal-arm balance.

3. Add distilled water until the test tube is 3/4 full. Stir the mixture gently with a glass stirring rod so that all the baking soda dissolves. ❶ Set the test tube aside. Record the color of the solution in Table 17·2. Also record how soluble the baking soda was in water. Wash the stirring rod.

4. Place about 2 gm of copper sulfate in a test tube. Record the color of the copper sulfate. Add distilled water until the test tube is 3/4 full. Stir the mixture gently with a glass stirring rod until the copper sulfate dissolves. Pour the solution into a beaker. ❷ Record the color of the solution and the solubility of copper sulfate in water (Table 17·2).

❷

Copper II sulfate is poisonous. Have students keep their hands away from their mouths while using it.



5. Pour the baking-soda solution (from step 3) into the copper-sulfate solution (from step 4). Notice what happens. Record the color of the mixture in Table 17•3.

6. Filter the mixture. ❸ Record the color of the liquid in the beaker and of the solid on the filter paper.

7. Place 2 ml of the liquid on an evaporating dish. Let it stand until the next class period. Record the color of the substance in the dish (Table 17•3).

Observing . . .

Table 17•2

Substance	Color of solid	Soluble in water?	Color of solution
Baking soda	White	Yes	Colorless
Copper sulfate	Dark blue	Yes	Blue

Table 17•3

Substance	Color	Soluble in water?
Baking soda + copper sulfate	Bluish-white	Variable, may be partly soluble.
Solid on filter paper	Light blue-green	No
Liquid in beaker	Light blue	XXXX
Solid on evaporating dish	White crystals & blue crystals	Yes

Name ______________________

Date __________ Class __________

Interpreting . . .

1. Did you see any evidence of a chemical change when the baking-soda and copper-sulfate solutions were mixed? If so, what?

   Yes. When the two solutions were mixed, bubbles were formed and a solid was formed.

2. Does the solid on the filter paper seem to be the same substance as the baking soda or as the copper sulfate? Explain your answer.

   Neither. The solid is a blue-green powder. It looks different and does not dissolve in water.

3. Do you think the liquid in the beaker after filtration is a solution either of baking soda or of copper sulfate? Explain your answer.

   No. It is a different color than the two original solutions.

Tying ideas together:

1. What do all of the investigations in this problem have in common?

   Chemical reactions took place.

2. Name as many signs as you can think of that may indicate a chemical reaction has taken place or is taking place. Give an example of each.

   a) Color change (bromthymol blue turned yellow).
   b) Change in texture (paper became ashes).
   c) Bubbles form (bubbles formed around zinc in acid).
   d) Solutions combine to form a solid (copper-sulfate and baking-soda solutions).

3. In your own words, define "chemical property."

Variable.

4. Name a chemical property of the following materials.

a) Aluminum	It reacts with bases.
b) Steel wool	It burns. It rusts.
c) Zinc	It reacts with acids.
d) Baking soda	It gives off a gas when heated. It reacts with copper sulfate in solution to form a solid (and a gas).
e) Paper	It burns.
f) Copper sulfate	It reacts with baking soda in solution to form a solid (and a gas).

Before you continue, read "Chemical changes" and "Some evidence of chemical change," pages 427–431 in your text.

Name ______________________

Date __________ Class __________

PROBLEM B: *Is there an energy change in chemical reactions?*

Materials:

1 Paper cup, large
1 Stirring rod
2 Beakers, 150 ml
2 Styrofoam cups
1 Balance and masses
1 Eye dropper
1 Graduate cylinder, 100 ml
1 Pair of safety glasses
1 Thermometer, –10°C to 110°C
Baking soda (sodium bicarbonate)
Washing soda (sodium carbonate)
Plaster of Paris
Vinegar (acetic acid)
Bromthymol blue
Household ammonia (ammonium hydroxide)
Water
Epsom salts (magnesium sulfate)

Have a gallon of tap water set aside so that it will be at room temperature by the time class begins.

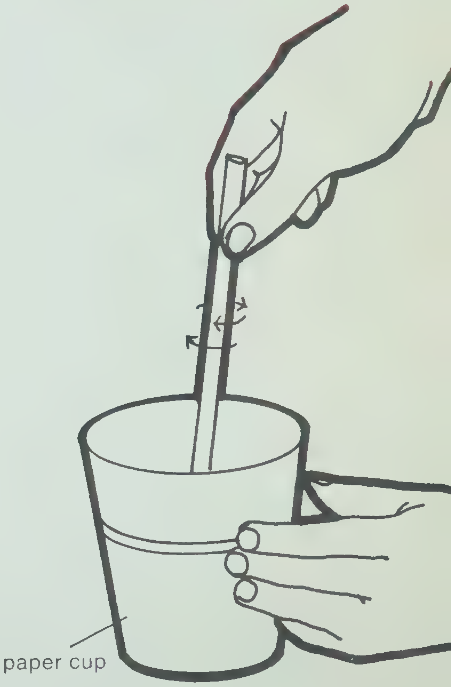
Have students remove stirring rods from the plaster before it hardens.

I Investigating . . .

1. Put on your safety glasses.

2. Fill a paper cup about half full with dry plaster of Paris. Fill a beaker half full of *room-temperature* water. Feel the outside of the cup and the outside of the beaker.

3. Add the water to the plaster of Paris and stir. Feel the outside of the cup while you stir and while the plaster hardens. Describe your observations.



Observing . . .

After the water is added to the plaster of Paris, the cup feels warm. The cup becomes hot as the mixture is stirred.

Interpreting . . .

1. Is there any reason to believe that a chemical change took place? If so, what?

   Yes. The cup became hot when the plaster and water were combined.

2. Is there any evidence that energy was released when the plaster and water were mixed? If so, what?

   Yes. Heat was generated.

II Investigating . . .

1. Put on your safety glasses.

STOP

AVOID putting your face directly over the cup of ammonia. Breathing in ammonia fumes can be dangerous.

2. Pour 50 ml of ammonia into a Styrofoam cup. Record the color of the ammonia in Table 17•4.

3. Pour 50 ml of vinegar into a beaker. Add 5 drops of bromthymol blue to the vinegar. Record its color.

Review how to read a thermometer for accurate measurement.

4. Measure the temperature of the ammonia and record it in Table 17•4. Then clean your thermometer.

5. Measure the temperature of the vinegar and record it.

6. Now add the vinegar to the ammonia. Stir the vinegar and ammonia. Measure and record the temperature of the combination. Record the color of the combination (Table 17•4).

Observing . . .

Temperature changes here are small.

Table 17•4

Substance	Temperature, °C	Color
Ammonia	Room temperature	Cloudy
Vinegar	Room temperature	Yellow
Combination	Variable—Temperature should rise	Blue

Interpreting . . .

What evidence can you give that a chemical change took place?

The temperature rose. The solution changed color.

Name ____________________

Date __________ Class __________

III **Investigating . . .**

1. Put about 150 ml of water into a Styrofoam cup. Measure the temperature of the water. Record it in Table 17•5.

2. Put a level teaspoon of baking soda into the water. Stir with a stirring rod. Measure and record any change in temperature.

3. Now add 3 more teaspoons of baking soda to the water, *one at a time*. Record the temperature each time you add a teaspoon of baking soda.

Observing . . .

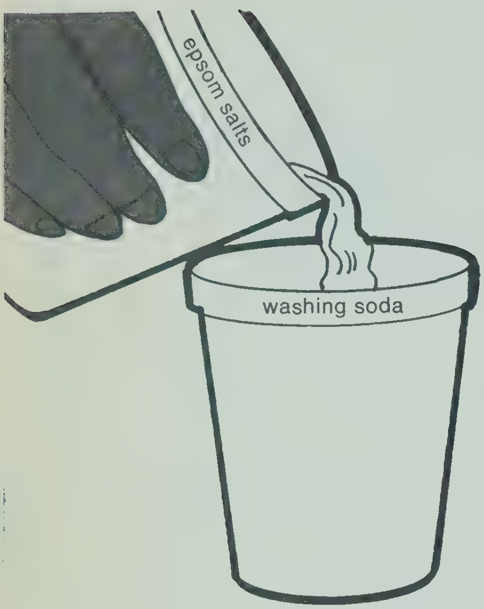
Table 17•5

Substance	Temperature, °C
Distilled water	Room temperature
Distilled water + 1 teaspoon baking soda	
+ 2 teaspoons baking soda	Variable: Temperature
+ 3 teaspoons baking soda	should drop 1 or 2°C
+ 4 teaspoons baking soda	with every addition.

Interpreting . . .

What evidence is there that a chemical change took place?

The temperature dropped.



IV **Investigating . . .**

1. Put on your safety glasses.
2. Put 50 ml of water in each of 2 beakers.
3. Add 10 gm of washing soda to one beaker. Add 10 gm of Epsom salts to the other. Stir the contents of each beaker. Let both stand for 5 minutes.
4. Measure the temperature of each solution. Record the temperature in Table 17•6.
5. Add the Epsom salts to the washing-soda solution. Stir the mixture. Then record the temperature of the combination.

Observing . . .

Table 17•6

Substance	Temperature, °C
Washing-soda solution	Room temperature.
Epsom-salts solution	Slightly below room temperature.
Combination	Temperature should fall.

Interpreting . . .

1. What evidence is there that a chemical change took place in this activity?

   The mixture of Epsom-salts and washing-soda solutions got cooler.

2. Was any energy involved in that change? Give evidence to support your answer.

   Yes. The temperature dropped. (Heat energy was absorbed.)

Name ____________________

Date __________ Class __________

Tying ideas together:

1. What do the following two chemical reactions have in common?

   a) Hardening of plaster   b) Burning of wood

   They both give off heat.

2. The heat given off when coal burns can be explained as a chemical reaction in which energy is *released* to the surroundings. How would you explain what happens in a chemical reaction like baking soda dissolving in water?

   The reaction absorbs energy from the surroundings.

Before you continue, read "Energy and chemical reactions," pages 432–433 in your text.

Name ____________________

Date __________ Class __________

PROBLEM C: ***What are some things that affect the speed of a chemical reaction?***

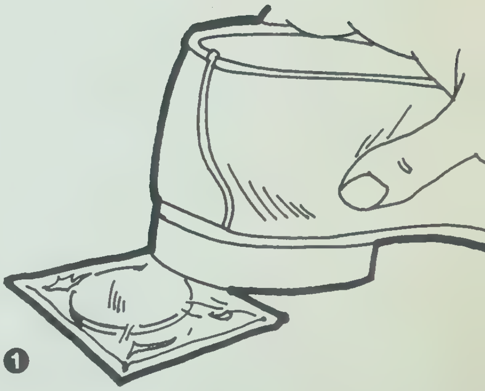
Materials:
2 Beakers, 150 ml
1 Graduate cylinder, 10 ml
8 Test tubes
1 Thermometer, -10°C to 110°C
1 Graduate cylinder, 100 ml
1 Eye dropper
1 Pair of safety glasses
Potassium iodide solution
Potassium persulfate solution #1
Potassium persulfate solution #2
Alka-Seltzer
Starch solution
Copper bead
Clock
Test-tube rack

I **Investigating . . .**

1. Pour 100 ml of water into each of 2 beakers. Set the beakers on paper towels.

2. Gently remove one Alka-Seltzer tablet from its foil wrapper. Shut the foil wrapper tightly. Carefully pound the tablet left in the wrapper with the heel of your shoe. ❶

3. Open the top of the foil so the crumbled tablet will pour out easily. Hold the container of crushed Alka-Seltzer in one hand and the whole tablet in the other. At the same moment, drop the tablet into one beaker of water and empty the packet into the other. ❷



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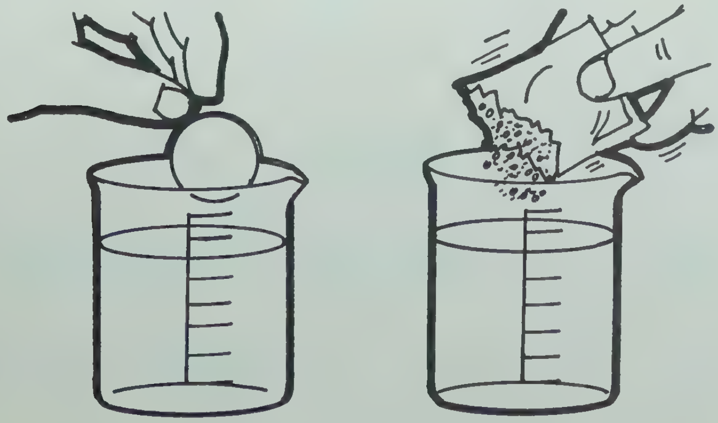
Watch to see which reacts more rapidly. Record your observations in Table 17·7.



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Observing . . .

Table 17·7

	Description of reaction
Solid tablet	Bubbles gently for a long time.
Crushed tablet	Bubbles very rapidly. Shoots out top of beaker.

Interpreting . . .

1. How is the crushed tablet different from the solid tablet?

   The crushed tablet is made up of many tiny pieces.

Discuss the concept of surface area.

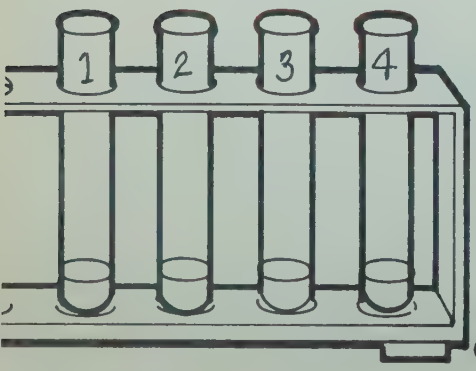
2. The amount of space around the surface of an object is called its *surface area*. Did the crushed tablet or the solid tablet have a greater surface area? Explain your answer.

   The crushed tablet. The total surface area of all the tablet particles is greater than the total surface area of the solid tablet.

3. What do you think caused any difference in the speed of the reaction?

   There was more of the crushed tablet in contact with the water.

Iodine is freed in this reaction to react with starch and form a blue-black complex molecule. Directions for making up the solutions for this problem are on page 261 in the Teacher's Appendix.



❶

II Investigating . . .

1. Put on your safety glasses.
2. Pour 2 ml of potassium iodide solution into each of 4 test tubes.
3. Add 2 drops of starch solution to each. Number the tubes and put them in your rack. ❶

Name ______________________

Date __________ Class __________

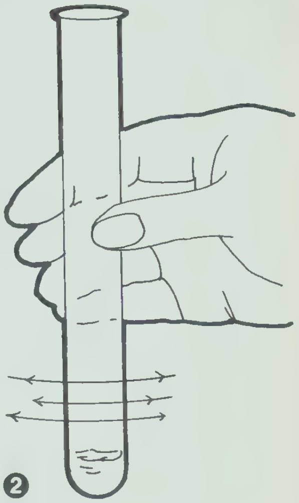
4. Pour *1 ml* of potassium persulfate solution #1 into test tube #1.

5. Shake test tube #1 gently. ❷ Time exactly how many seconds pass before a change takes place. Record the change and the time for the change in Table 17•8.

6. Pour *2 ml* of potassium persulfate solution #1 into test tube #2. Record your observations, as you did in step 5.

7. Repeat the experiment using potassium persulfate solution #2. Pour *1 ml* of potassium persulfate solution #2 into test tube #3. Record your observations in Table 17•8.

8. Pour *2 ml* of potassium persulfate solution #2 into test tube #4. Record your observations.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Observing . . .

Table 17•8

Solution	Amount	Change observed	Seconds before change
Potassium persulfate #1	1 ml	Turns dark blue	About 120
Potassium persulfate #1	2 ml	Turns dark blue	About 60
Potassium persulfate #2	1 ml	Turns dark blue	About 80
Potassium persulfate #2	2 ml	Turns dark blue	About 40

Interpreting . . .

1. Did increasing the number of milliliters of potassium persulfate solution (Table 17•8) increase or decrease the amount of time before a change took place?

   It reduced the time.

Solution #2 has twice as much potassium persulfate dissolved in each milliliter as solution #1. In other words, solution #2 is twice as *concentrated* as solution #1.

2. How did increasing the concentration of potassium persulfate in each milliliter of solution affect the amount of time needed for a change?

   It reduced the time.

III **Investigating . . .**

Make sure students remove their beakers from the heat source before placing the test tubes in the beakers.

1. Put on your safety glasses.
2. Pour 100 ml of water into a beaker and heat it until it is 50°C. Remove the beaker from the heat.
3. Pour 2 ml of potassium iodide solution into a test tube. Add 2 drops of starch solution.
4. Pour 1 ml of potassium persulfate solution #1 into another test tube.
5. Use tongs to put both test tubes into the beaker of 50°C water.
6. After ten minutes, measure the temperature of the water. Assume that both solutions are the same temperature now. Record the temperature in Table 17•9.
7. Use tongs to quickly pour the potassium persulfate into the potassium iodide. Shake the mixture gently. Time exactly how many seconds pass before a color change takes place. Record the time in Table 17•9.

Repeat the above experiment, but this time heat the water in the beaker to 80°C. Be sure to use tongs to remove the beaker from the heat. Record your observations.

Name ____________________

Date __________ Class __________

Observing . . .

Table 17•9

Reactants	Temperature, °C	Seconds before change
Potassium iodide + potassium persulfate	About 50°	About 40
Potassium iodide + potassium persulfate	About 80°	Less than 15

Interpreting . . .

1. How does an increase in temperature affect the time needed for a chemical change? Try to explain your answer. (Hint: Do you remember what you learned about diffusion? If not, turn to page 386 of your text.)

   The time decreases. Substances mix faster at higher temperatures.

2. What do you think would happen to the speed of a chemical change if you put two reactants in ice water for 10 minutes?

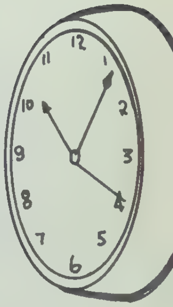
   It would take longer for a change to occur.

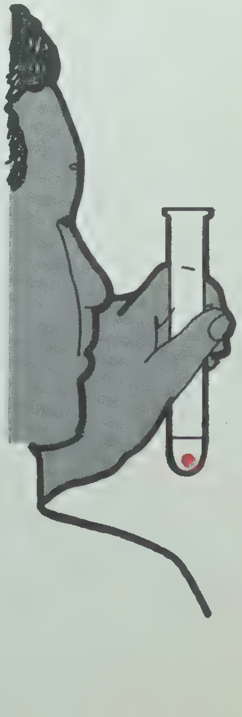
IV **Investigating . . .**

1. Put on your safety glasses.

2. Pour 2 ml of potassium iodide solution into a test tube. Add 2 drops of starch solution. Quickly add 1 ml potassium persulfate solution #1 to the potassium iodide and shake gently.

3. Time exactly how many seconds pass before a color change takes place. Record the time in Table 17•10.





Take two clean test tubes and repeat the above experiment. But add a copper bead to the potassium iodide before you pour in the potassium persulfate. Note the time needed for a change. Record it in Table 17•10.

Observing . . .

Table 17·10

Reactants	Any material added?	Seconds before change
Potassium iodide + potassium persulfate	No	Variable
Potassium iodide + potassium persulfate	Copper bead	1/2 as long as above

Interpreting . . .

Substances that change the speed of a chemical reaction without changing chemically themselves are called *catalysts.* Is the copper bead a catalyst? Why?

Yes. It cut the time in half.

Tying ideas together:

What four things affected the rate at which a chemical reaction took place in your experiments?

Surface area, quantity (concentration), temperature, and presence of a copper bead (catalyst).

Now read "Changing the speed of a chemical reaction," pages 434–436 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Describe four types of chemical reactions, based on the experiments you have done so far.
2. Perform an experiment to demonstrate how the surface area of two reacting substances affects the speed of a chemical reaction.
3. Perform an experiment to demonstrate how the concentration and the temperature of two reacting substances affect the speed of a chemical reaction.
4. Demonstrate one effect of using a catalyst.

Name ____________________

Date __________ Class __________

CHAPTER 18: METALS

BEFORE YOU BEGIN PROBLEM A . . .

Read "Metals" and "The Marvels of Metals," pages 455–461 in your text.

Now look carefully at the pieces of metal that have been placed in the classroom for you. Your teacher put water on the metal pieces and then left them out in the air overnight.

The samples on the table in front of the class should be strips of metal like those for the displacement experiments in Problem A. You might add a strip of silver and a strip of lead.

Notice which metals reacted with the oxygen in the air. Notice which metals reacted just a little, which reacted a lot, and which (if any) did not react at all.

Lift the pieces of metal and notice which are light and which are heavy. Try to bend them. Notice which are stiff and which bend easily. Then think about these questions:

—Would rust be a problem if car bodies were made of copper?

—Why aren't tin cans made only of tin?

—Why do some metals react with the oxygen in the air while others do not?

PROBLEM A: *How can you arrange a group of metals according to the way they react with each other?*

Materials:

4 Copper strips
4 Iron strips
4 Tin strips
4 Zinc strips
4 Beakers
1 Pair of safety glasses

100 ml Solution A
100 ml Solution B
100 ml Solution C
100 ml Solution D

To find the number of metal strips needed, turn to page 262 in the Teacher's Appendix.

The solutions are to be unknown so the students will have to observe the reactions. Directions for making up the solutions are on page 262.

Plastic beakers are recommended because they are less expensive than glass, unbreakable, and can be stacked—thus occupying less space.

Investigating . . .

1. Put on your safety glasses.
2. Pour 100 ml of solution A into a beaker. Label the beaker with the letter identifying the solution. Do the same thing with each of the other solutions.

3. Take the four strips of metal assigned to your laboratory group. Place one metal strip in each solution.

4. Record any changes you see in the appearance of the strips by the end of the class period (Table 18·1). Set the beakers and strips aside until your next laboratory period.

Observe the strips again. Record any other changes that have taken place overnight.

Observing . . .

Have students compare their results to fill in their observation sections.

Look at the metal strips and solutions of ALL the lab teams in your class. Then complete the following table by writing a brief description of each reaction (if one has occurred).

Name ____________________

Date ________ Class ________

Table 18•1

Solution	Copper	Iron	Tin	Zinc
A Iron	No change	No change	No change	Coating on strip
B Zinc	No change	No change	No change	No change
C Tin	No change	Black coating on the strip	No change	Black coating on strip
D Copper	No change	Copper coating on the strip	Copper coating on the strip	Copper coating on the strip

Interpreting . . .

Each of the solutions you used has a metal dissolved in it. Your teacher will tell you what metal is in each solution. Write the name of that metal in the table, under the letter of the proper solution.

If the metal of the strip is *more reactive* than the metal in the solution, the metal of the strip will *displace* the metal from its solution. That is, some of the metal of the strip will enter the solution and some of the metal in the solution will form a layer on the strip.

1. List the *metal strips* according to the way they reacted with the metals in solution. Start with the strip that displaced the most metals from the solutions and end with the strip that displaced the fewest metals from the solutions.

   Zinc, iron, tin, copper

2. List the *metals in solution* according to the way they reacted with the metal strips. Start with the metal that is displaced from solution the most and end with the metal that is displaced from solution the least.

   Copper, tin, iron, zinc

Before you continue, read "The chemistry of metals" and "Using displacement reactions," pages 462–470 in your text.

Name ____________________

Date __________ Class __________

PROBLEM B: ***What are some ways to prevent rusting?***

Materials: 2 Painted iron strips
2 Galvanized iron pipe sections
1 Uncoated iron strip
2 Tin cans
5 Beakers
1 Pair of safety glasses
Carbonated salt water
Iron file

Galvanized iron pipe is available from your local hardware store or any large retail catalog. Use very small sections. Have the students save empty tin cans for this activity. Use any spray enamel to paint the iron strips.

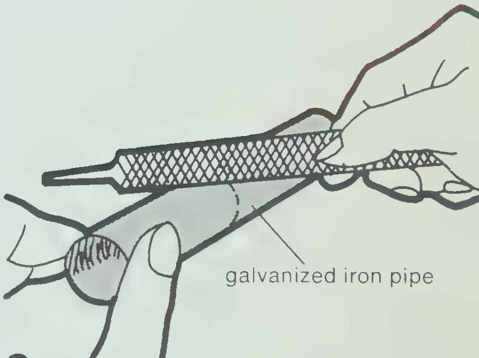
The corrosive environment for this activity is a carbonated salt water. To make it, dissolve 2 Alka-Seltzer tablets in 1000 ml of 3.5% salt water. Make the 3.5% salt water by dissolving 35 gm of sodium chloride in 500 ml of tap water and diluting to 1000 ml.

Investigating . . .

1. Put on your safety glasses.

2. Pour 100 ml of carbonated salt water into each of your five beakers.

3. Take two *galvanized* iron pipe sections. *Galvanized* means that the iron pipe has been coated with a layer of *zinc*. Scratch the surface of one pipe section with a file. ❶ Put each pipe section in a beaker of carbonated salt water.



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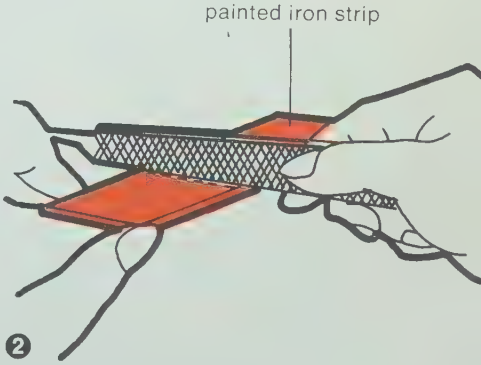
4. Next, take two painted iron strips. Scratch the surface of one iron strip, as you did in step 3. ❷ Put each iron strip in a beaker of carbonated salt water.



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5. Pick out an uncoated, unpainted iron strip. Put it in the remaining beaker of salt water.

6. Last, pick out two tin cans. Scratch the inner surface (near the bottom) of one tin can. Put 100 ml of carbonated salt water into each of your tin cans.

7. Make sure all the scratches you made are below the surface of the solution in each beaker. Then set the samples aside until your next lab period.

8. Record any changes that have taken place in the scratched and unscratched samples.

Observing . . .

Table 18•2

Metal	Description (change on surface of metal or in the color of the salt-water solution)
Galvanized iron pipe	Some salt clinging to outside of pipe. Solution unchanged.
Scratched galvanized pipe	Some salt clinging to outside of pipe. Slight brownish cast to solution.
Painted iron strip	No change to strip or solution.
Scratched painted strip	Scratched area rusted. Solution light brown color.
Iron strip	Badly rusted. Solution is dark brown.
Tin can	No change in can or solution.
Scratched tin can	Scratches look rusted. Solution unchanged.

Name ______________________

Date __________ Class __________

Interpreting . . .

1. Why do you think many "outdoor" garbage cans are made of *galvanized* iron? Use your observations to support your answer.

   Galvanized iron does not rust. The zinc coating prevents the iron from rusting.

2. A tin can is only *coated* with tin. Underneath the tin is a layer of steel. If some of the tin coating were scratched off, do you think the food inside the can would spoil? Try to explain your answer.

   Yes. The food could react with the exposed metal, just as the salt water reacted with the metal. The reaction might change the food chemically and cause it to spoil.

3. What advantage can you think of for using paint as a protection against rusting, instead of using a metal coating?

   Paint is easier to put on than a metal coating. It costs less to apply and may weigh less than a metal coating.

Now read "Avoiding rust," pages 484–485 in your text.

SOME THINGS YOU SHOULD BE ABLE TO DO NOW:

1. Arrange a group of metals in a series according to their ability to displace each other from solution.
2. Perform an experiment to find which metal, in a group of metals, is the most reactive, according to its ability to displace other metals from solution.
3. Make a prediction about the effect oxygen in the air will have on uncoated iron, iron coated with paint, and iron coated with certain metals.

Name ____________________

Date __________ Class __________

APPENDIX A: RENEWING YOUR SKILLS

ACTIVITY A: *Measuring length*

Materials: Meter stick
Yardstick
Ruler with metric scale and English scale

Investigating . . .

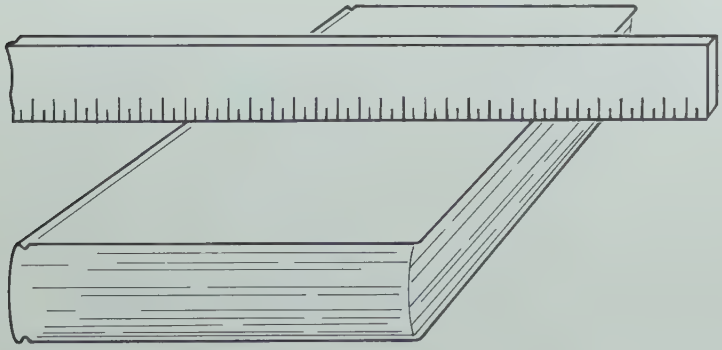
Read pages XIV and 513-515 in your text.

1. Notice the numbers on the metric side of the ruler and on your meter stick. These numbers stand for *centimeters* (cm). Record how many centimeters are in one meter.

2. Each centimeter on your metric ruler (and perhaps on your meter stick) is divided into smaller sections. These smaller sections are called *millimeters*. Record how many millimeters are in a centimeter.

Note: Look closely at the first few sections of your ruler. Notice if the sections are too long or too short. If they are, it's a good idea not to use them for measuring short distances because your results will not be accurate.

When you measure very short distances, it's also a good idea to place the ruler on its edge, rather than on its side. Why do you think you would get more accurate results in this way?



3. Now use the metric scale on your ruler to measure the width of your textbook in centimeters. Also measure it in millimeters. Record your measurements in Table A·1.

4. Measure the width of your textbook in inches. Record your measurements.

In the next series of measurements you will not get whole units every time. Record your measurements in the best way you can.

5. Use your meter stick to measure the short side of your desk or laboratory table. Record the length in centimeters (Table A·1). Also record the length in millimeters. Then measure the same side of the table in inches. Again record your measurements.

6. Measure the height of the classroom door and the width of your classroom. Use your meter stick and your yardstick each time. Give the distances in millimeters, centimeters, meters, and inches.

Observing . . .

A. Number of centimeters in a meter: 100

B. Number of millimeters in a centimeter: 10

C. Table A·1

	Millimeters (mm)	Centimeters (cm)	Meters (m)	Inches (in)
Width of textbook	200	20.0	.02 or 2/100	7 13/16
Width of table or desk	Variable			
Height of door				
Width of classroom				

Name ______________________________

Date __________ Class __________

Interpreting . . .

1. What three metric units of length did you use in this activity?

   millimeter, centimeter, and meter

2. Compare a 2.5-cm distance on the metric scale of your ruler with a 1-inch distance on the other scale. Count the number of small divisions or mm in the 2.5 cm distance. Then count the number of small divisions or fractions in the 1-inch distance. From this observation, what do you think is one advantage of the metric scale?

   Variable. The metric system works easily in units of ten and has a smaller basic unit, the millimeter.

3. When you were measuring distances in centimeters and meters you probably found that your measurements did not always come out in complete centimeters or complete meters. How did you record the leftover parts of a centimeter or meter?

   Variable. Possible answers: (a) as fractions of centimeters or meters; (b) parts of centimeters as millimeters; (c) parts of meters as centimeters or millimeters.

4. The length of your textbook is 239 mm *or* 23.9 cm. When the textbook is measured in cm, the *0.9* represents 9 small leftover sections of a centimeter. What are these sections called?

   millimeters

5. If a lunchroom table is 224 cm long, how would you give that measurement just in meters? (Hint: Give your answer in decimals. There are 100 cm in a meter. So the "leftover" 24 cm are 24/100 of a meter.)

   2.24 m

6. If a table is 75 cm high, how would you give that measurement just in meters? Your answer will be in decimals.

   0.75 m

7. Now go back to your Table A·1. If you did not give your measurements in *cm only* under the "Centimeters" column, do so now. Use decimals to show any leftover sections of a centimeter. If you did not give your results in *m only* under the "Meters" column, do that now also. Again, you will have to use decimals.

Name ______________________

Date __________ Class __________

ACTIVITY B: *Using decimals*

Addition and subtraction . . .

Decimals, like the metric system, are based upon the number 10. Our money is also a decimal system. Adding or subtracting decimals is like adding or subtracting dollars and cents.

To add or subtract decimals, start by writing the numbers so the decimal points are one below the other. Write 1.4 + 1.5 and 2.9 − 1.5 as follows:

$$\begin{array}{r} 1.4 \\ +1.5 \\ \hline \end{array} \qquad\qquad \begin{array}{r} 2.9 \\ -1.5 \\ \hline \end{array}$$

Then add or subtract as if they were whole numbers:

$$\begin{array}{r} 1.4 \\ +1.5 \\ \hline 2\ 9 \end{array} \qquad\qquad \begin{array}{r} 2.9 \\ -1.5 \\ \hline 1\ 4 \end{array}$$

And bring the decimal point straight down into the answer:

$$\begin{array}{r} \downarrow \\ 1.4 \\ +1.5 \\ \hline 2.9 \end{array} \qquad\qquad \begin{array}{r} \downarrow \\ 2.9 \\ -1.5 \\ \hline 1.4 \end{array}$$

Look over each of the following examples:

$$\begin{array}{r} 13.54 \\ +\ 7.95 \\ \hline 21.49 \end{array} \qquad \begin{array}{r} 4.38 \\ -1.50 \\ \hline 2.88 \end{array} \qquad \begin{array}{r} 3.45 \\ +\ \ .65 \\ \hline 4.10 \end{array} \qquad \begin{array}{r} 6.00 \\ -4.79 \\ \hline 1.21 \end{array}$$

Now try these:

$$\begin{array}{r} 5.62 \\ +\ .91 \\ \hline 6.53 \end{array} \qquad \begin{array}{r} 9.26 \\ -7.98 \\ \hline 1.28 \end{array} \qquad \begin{array}{r} 7.18 \\ +8.07 \\ \hline 15.25 \end{array} \qquad \begin{array}{r} .95 \\ -.44 \\ \hline .51 \end{array}$$

Multiplication . . .

Multiply decimals as if they were whole numbers:

$$\begin{array}{r} 22.4 \\ \times\ .02 \\ \hline 448 \end{array}$$

Then count the number of decimal places:

$$\begin{array}{rl} 22.4 & \leftarrow \text{1 decimal place} \\ \times\ .02 & \leftarrow \text{2 decimal places} \\ \cline{1-1} 448 & \end{array}$$

Add up all the decimal places and mark off the number of places in the answer:

$$\begin{array}{rl} 22.4 & \\ \times\ .02 & \text{3 decimal places} \\ \cline{1-1} .448 & \text{3 decimal places} \end{array}$$

Note: The total number of decimal places in the two figures you are multiplying will be the number of decimal places in your answer.

Look over each of the following examples:

$$\begin{array}{r} 30 \\ \times .03 \\ \hline .90 \end{array} \qquad \begin{array}{r} 1.5 \\ \times\ .3 \\ \hline .45 \end{array} \qquad \begin{array}{r} 4.3 \\ \times\ 4 \\ \hline 17.2 \end{array} \qquad \begin{array}{r} 5.8 \\ \times 3.2 \\ \hline 116 \\ 174 \\ \hline 18.56 \end{array}$$

Now try these:

$$\begin{array}{r} .86 \\ \times\ 4 \\ \hline 3.44 \end{array} \qquad \begin{array}{r} 148 \\ \times .42 \\ \hline 52.16 \end{array} \qquad \begin{array}{r} 2.29 \\ \times\ 8.6 \\ \hline 19.694 \end{array} \qquad \begin{array}{r} 3.1 \\ \times\ .9 \\ \hline 2.79 \end{array}$$

Name ______________________

Date ___________ Class ___________

Division . . .

To divide decimals, arrange the numbers as follows:

$$.21\overline{)2.94}$$

Then move both decimal points to make the divisor a whole number:

$$\underset{\curvearrowright}{.21}\overline{)\underset{\curvearrowright}{2.94}}$$

Place the decimal point in the answer:

$$\begin{array}{r} .\\ 21\overline{)294.} \end{array}$$

And divide as if you had whole numbers:

$$\begin{array}{r} 14.\\ 21\overline{)294.}\\ \underline{21}\\ 84\\ \underline{84} \end{array}$$

Look over each of the following examples:

$$\begin{array}{r} 58.\\ \underset{\curvearrowright}{.3}\overline{)\underset{\curvearrowright}{17.4}}\\ \underline{15}\\ 2\,4\\ \underline{2\,4} \end{array} \qquad \begin{array}{r} 1.5\\ \underset{\curvearrowright}{3.2}\overline{)\underset{\curvearrowright}{4.8}0}\\ \underline{3\,2}\\ 1\,6\,0\\ \underline{1\,6\,0} \end{array} \qquad \begin{array}{r} 2.8\\ \underset{\curvearrowright}{2.5}\overline{)\underset{\curvearrowright}{7.0}00}\\ \underline{5\,0}\\ 2\,0\,0\\ \underline{2\,0\,0} \end{array}$$

Now try these:

$$\begin{array}{r} 6.8\\ 3.2\overline{)21.76} \end{array} \qquad \begin{array}{r} 7.3\\ .9\overline{)6.57} \end{array} \qquad \begin{array}{r} 6.8\\ .02\overline{).136} \end{array}$$

$$\frac{4.5}{0.3} = 15 \qquad \frac{31.92}{.06} = 534 \qquad \frac{14}{20} = .7$$

Name ____________________

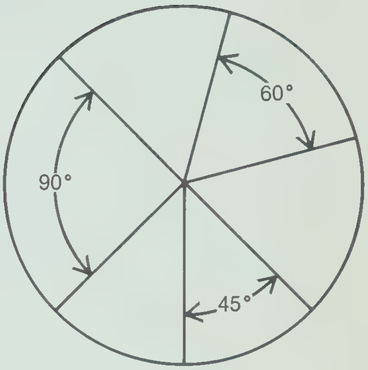
Date __________ Class __________

ACTIVITY C: ***Measuring angles with a protractor***

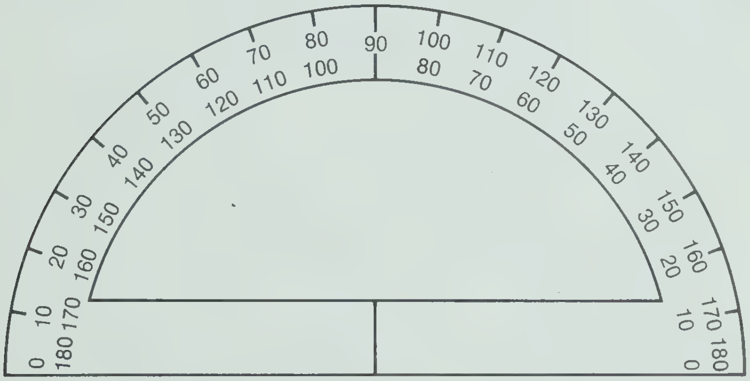
Materials: Protractor
(Turn to page 263 for cutout P.)

Investigating . . .

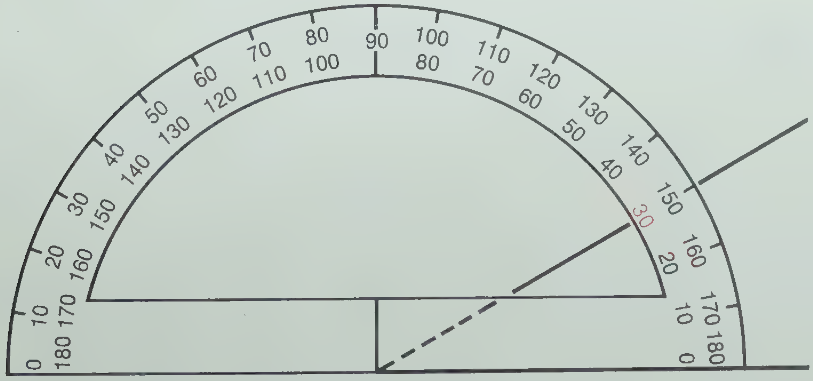
A circle is divided into 360 sections called *degrees.* An *angle* is a section of a circle. Angles are measured in degrees.



Cut out the cardboard protractor marked *P* from page 263. Notice that there are two scales on your protractor. One goes from left to right. The other goes from right to left.

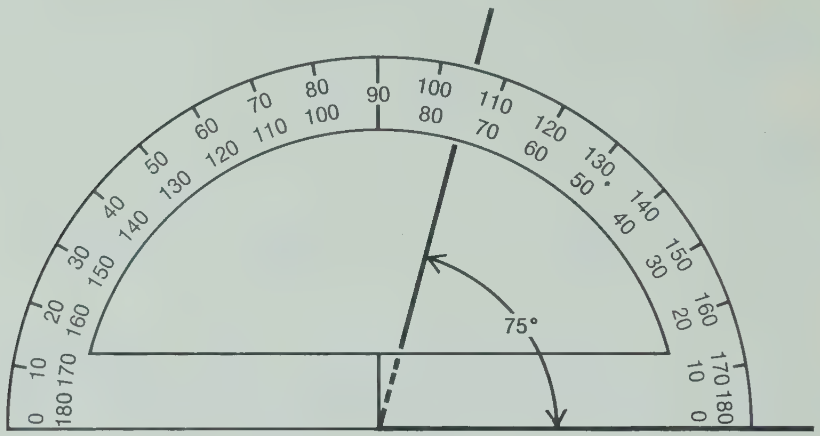


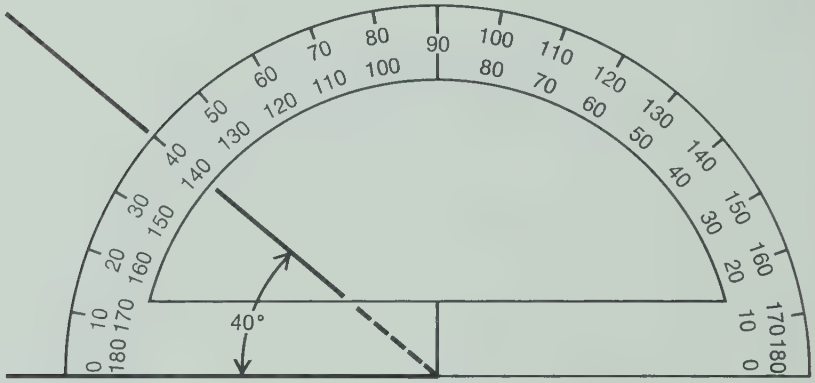
To measure an angle, place the bottom (flat) edge of the protractor along one side of the angle. Place the center line of the protractor at the point where the sides of the angle meet:



The zero point of one scale on the protractor will fall on one side of the angle. To find the size of the angle, read the number where the other side of the angle crosses that scale on your protractor.

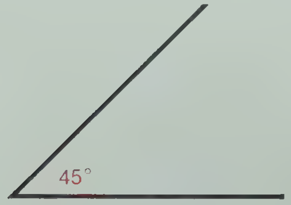
Look over each of these examples:

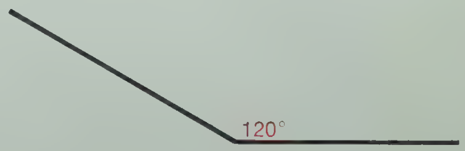


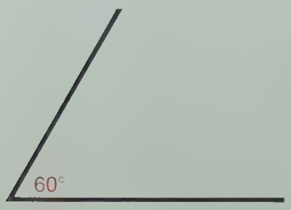


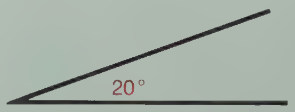
Observing . . .

Record the size of each of the angles below.









Name ____________________

Date __________ Class __________

ACTIVITY D: *Using graphs*

I Investigating . . .

It is often easier to understand the results of an experiment if you draw a graph. There are two kinds of graphs you can draw—*bar graphs* and *line graphs.*

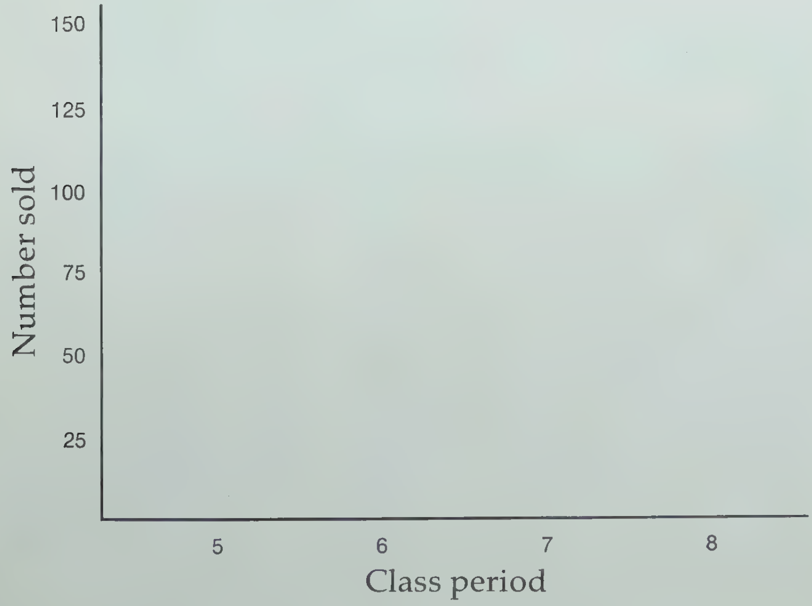
Here's how to make a bar graph:

A bar graph can be used to compare the sales of hot dogs and hamburgers in the school lunchroom during each lunch period. The information that will be shown in the graph is given in Table D·1.

Table D·1

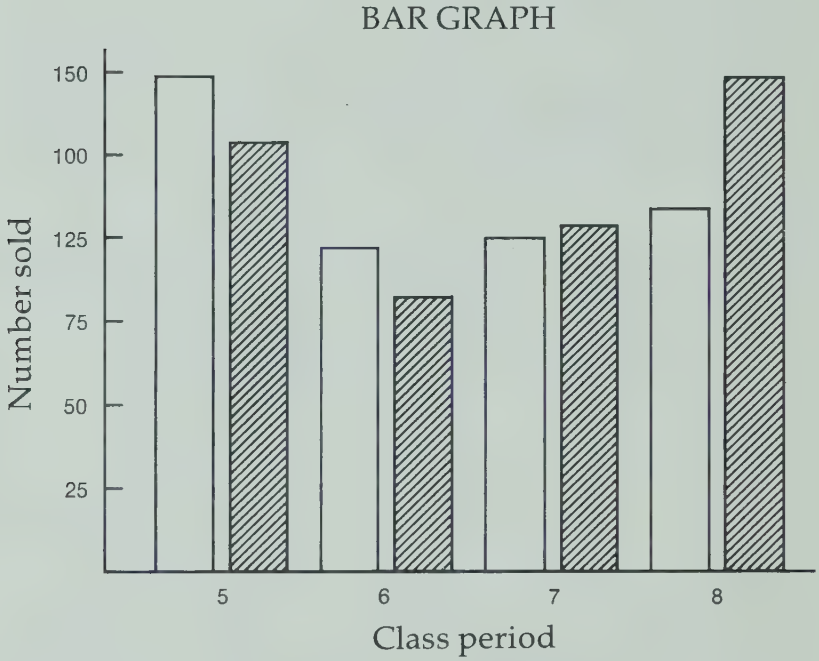
Class period	Hot dogs	Hamburgers
5	148	132
6	96	89
7	100	105
8	112	148

1. Decide what you want the length of the bars to show and in what direction the bars should go. Then draw the frame for the graph with numbers along the sides:



2. Choose a way to make it clear which bars represent each type of data:
   Solid bars—hot dogs
   Striped bars—hamburgers

3. Draw your bars on the graph. The length of each bar should show the number of items sold:



Here's how to make a line graph:

A line graph can be used to see how the number of hot dogs sold changes from day to day. The information that will be shown in the graph is given in Table D·2.

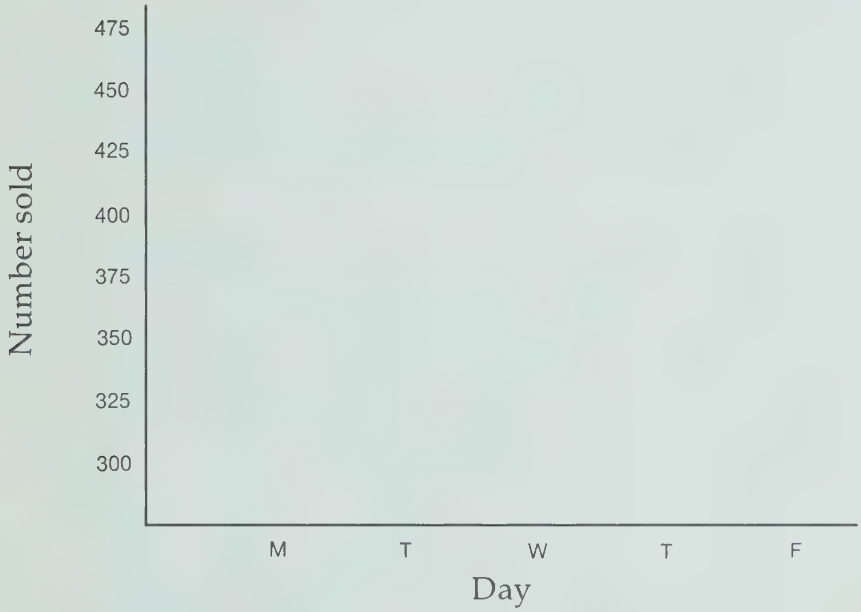
Table D·2

Day	Hot dogs sold
Monday	456
Tuesday	395
Wednesday	337
Thursday	294
Friday	343

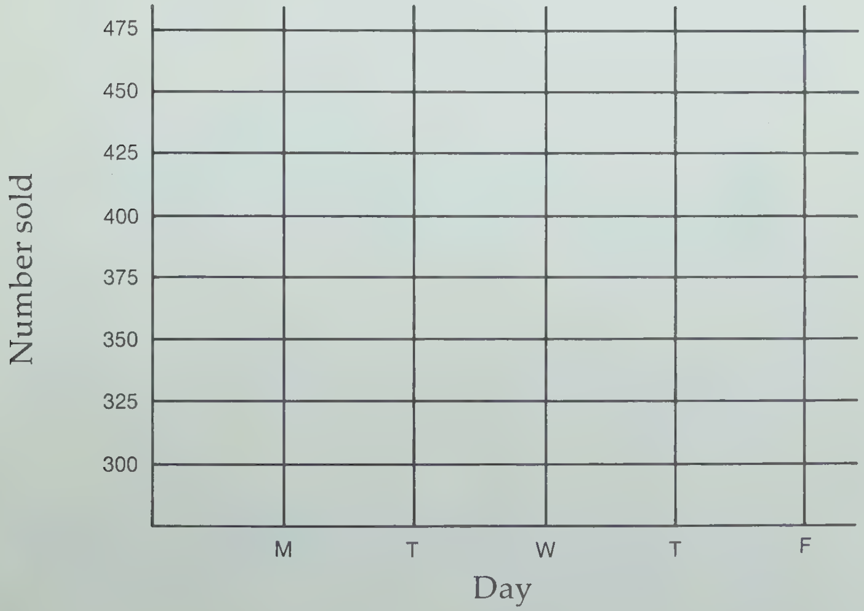
Name ____________________

Date __________ Class __________

1. Decide which information you want to show along each side of the graph. Then draw the frame for the graph with the numbers or names along the sides of the frame.



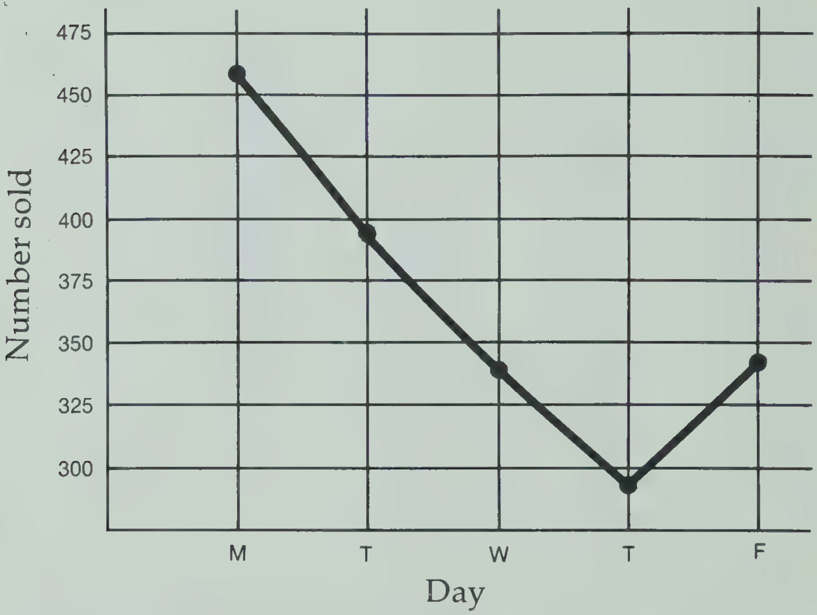
2. Draw the cross lines on the graph.



3. Plot the "points" in your table on the graph. For example, on Monday 456 hot dogs were sold. To plot this information on the graph, find Monday along the bottom line. Then follow up the vertical line at "Monday" until you are at 456 along the numbers on the side.

4. When all the data has been plotted, attach the points with a line.

LINE GRAPH



Observing . . .

Use your graphs to answer these questions.

A. During which period were the most hot dogs sold? Do you need to know how many were sold to answer this question?

5th period. No, you just need to see the longest bar.

B. During which period were the fewest hamburgers sold?

6th period

C. Which period had the greatest difference between the number of hot dogs sold and the number of hamburgers sold?

8th period

Name ______________________

Date __________ Class __________

D. On which day were the fewest hot dogs sold? Do you need to know how many were sold to answer this question?

Thursday. No, you just need to see the low point on the graph.

II **Investigating . . .**

1. Make a bar graph of the information in Table D•3. Use solid bars for potato chips and striped bars for french fries.

Table D•3: Sales of potato chips and french fries

Day	Potato chips bags	French fries orders
Monday	120	190
Tuesday	200	180
Wednesday	125	175
Thursday	155	185
Friday	110	140

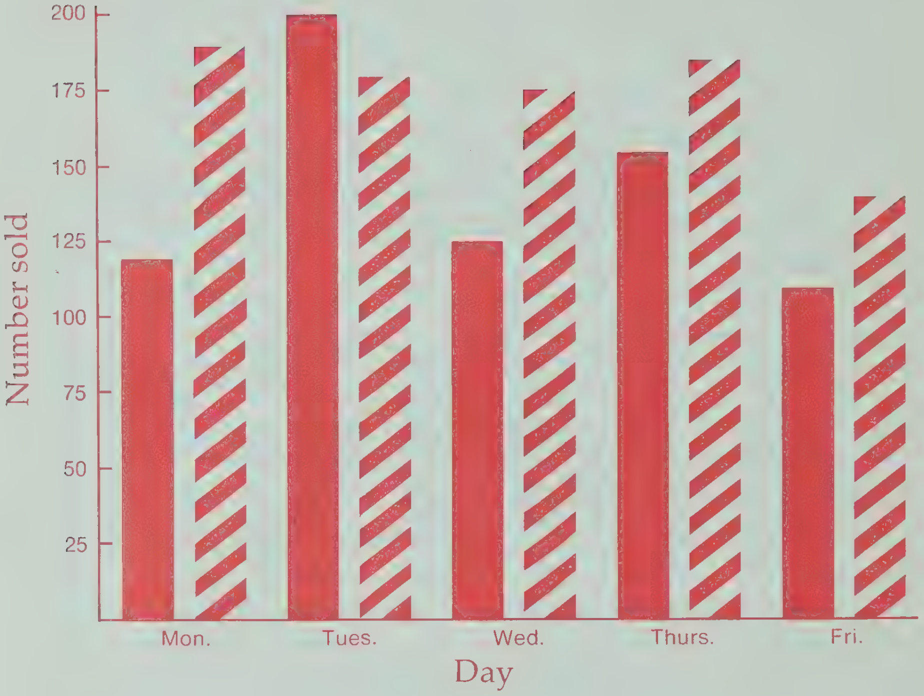
2. Make a line graph of the information in Table D•4.

Table D•4: Relationship between temperature and number of hot lunches sold

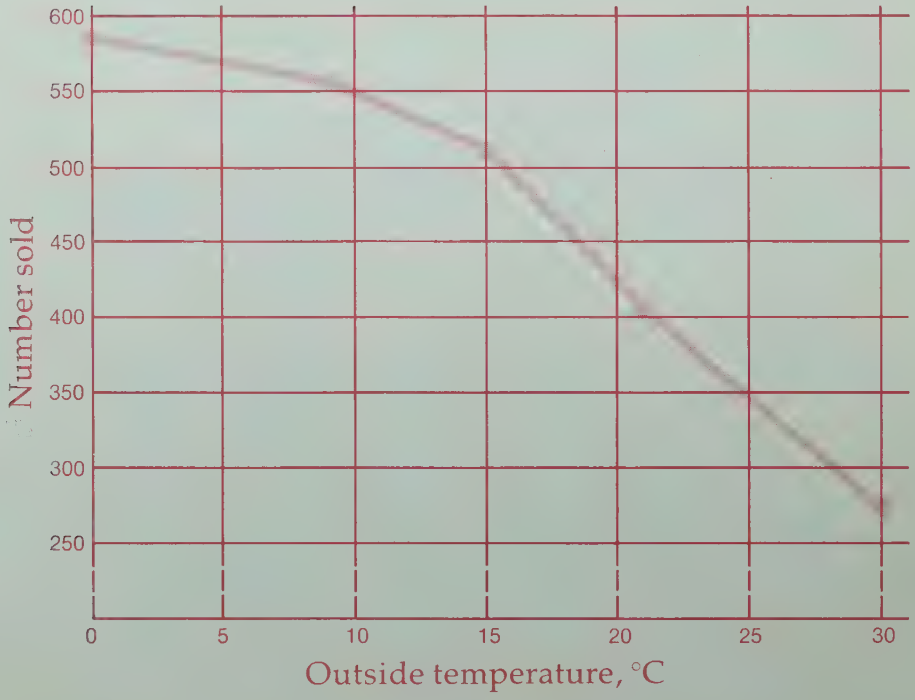
Outside temperature, °C	Hot lunches sold
21	406
30	275
9	558
15	512
0	585

Observing . . .

A. Bar Graph



B. Line Graph



Name ____________________

Date __________ Class __________

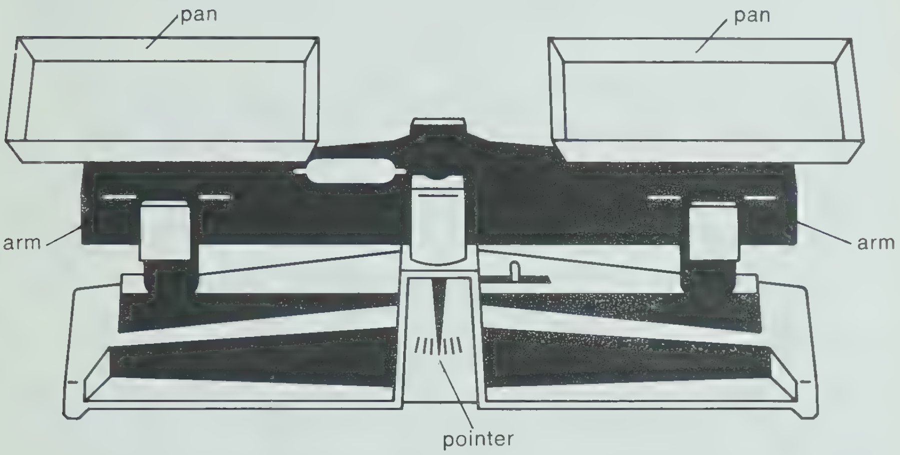
ACTIVITY E: *Measuring mass with an equal-arm balance*

Materials: Equal-arm balance
Set of standard masses
Common objects

Investigating . . .

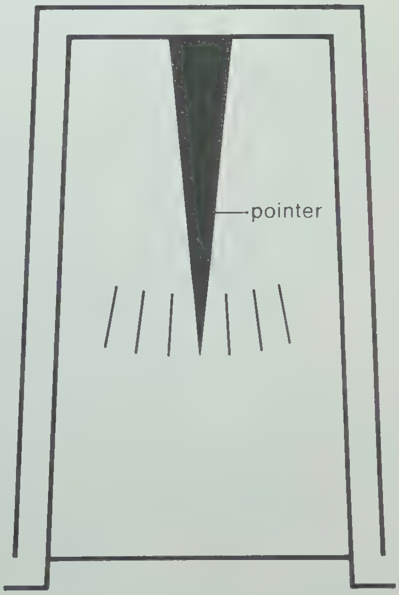
Look at your equal-arm balance. It has the same parts as the balance in the drawing:

The balance used throughout the laboratory book is an inexpensive equal-arm balance. It has been built for use by school children. The pointer on this balance points downward from the knife edge. The pointers on most beam balances and some more complex equal-arm balances point upward.



An equal-arm balance works like a seesaw. It is carefully supported in the center. The pull of gravity is the same on each side:

Notice the pointer in front of the black lines in the section in front of the balance. The pointer should be on the center black line when the balance is level.



Now place your pencil on the left-hand pan of the balance. Notice what happens to the pan and to the pointer. The pull of gravity is greater on the side with more mass.

You can level the balance. Just add something to the empty side. When objects of equal mass are on each side of the balance, the pull of gravity on each side will be the same. The balance will be level. But you will not know the mass of the pencil in standard units. To find the mass of the pencil, you must level the balance with standard masses. Here is how:

1. Look over your set of standard masses.

2. Record the sizes you have in your set. Also record the the total mass of your standard masses. Give the total in grams. Then give it in kilograms. Now choose the mass you think is closest to the mass of your pencil. Carefully put it on the right-hand pan of the balance.

3. Watch the pointer. When it stops swinging, notice where it is pointing. If the pointer is to the right of the center line, the standard mass you chose is less than the mass of your pencil. Add mass to the right-hand pan. Or put on a larger mass.

4. If the pointer is to the left of the center line, the standard mass is greater than the mass of your pencil. Remove it and try a slightly smaller mass. Continue adding and removing masses on the right-hand pan until the pointer becomes centered. When the pointer is centered, the mass on the right-hand pan is the same as that of your pencil. Record it in Table E•1.

Use the above procedure to find and record the mass in grams of each of the objects in Table E•1. Then give all the masses in *kg*. Your answers will be in decimals.

Observing . . .

A. Sizes of standard masses in your set: Vary according to equipment available.

B. Total mass of your standard masses: Variable.

C. Table E•1

Object	Total mass (gm)	Total mass (kg)
Pencil	Variable	
Quarter		
Eraser		
House key		

Name ____________________

Date __________ Class __________

ACTIVITY F: *Measuring liquid volume with a graduate cylinder*

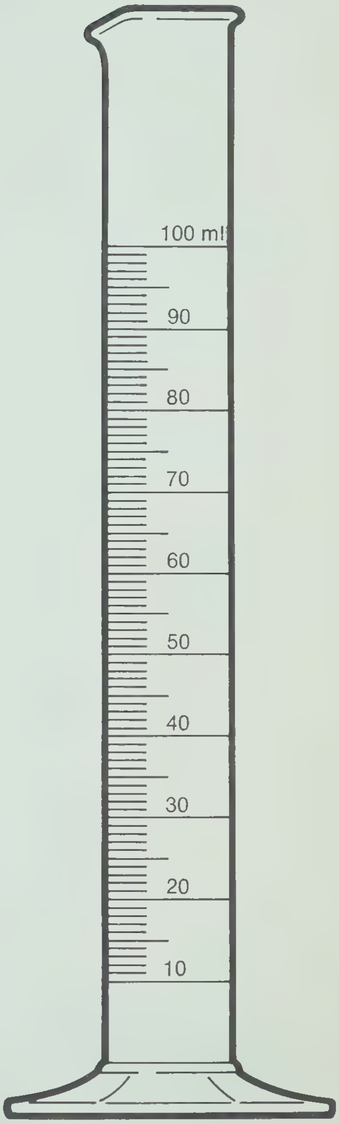
Materials: Graduate cylinder, 0-100 milliliters (ml)
Graduate cylinder, 0-10 ml
Water

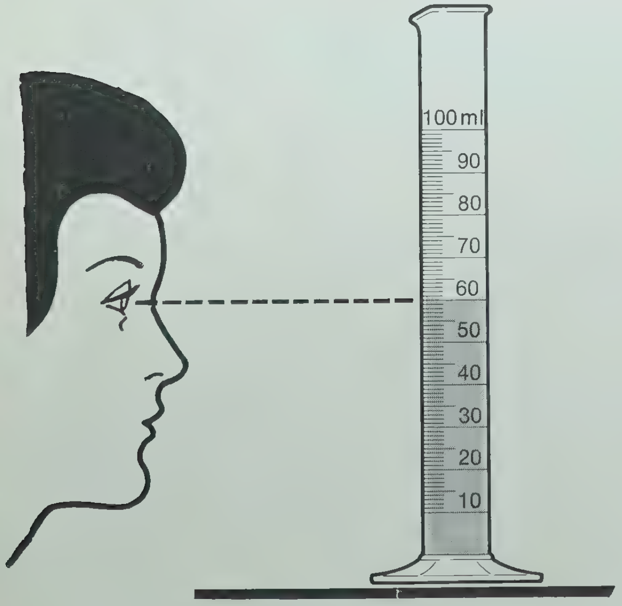
Investigating . . .

Volume is the measure of the amount of space taken up by a substance. In the metric system small amounts of liquid are measured in *milliliters.* One milliliter is the same as one cubic centimeter.

1. Notice the scale up the side of your 100-ml graduate cylinder. The numbers stand for milliliters (ml). Record how many sections there are between each number.

2. Pour water into your 100-ml graduate cylinder until it is about half full. Let the cylinder sit on your desk until the water is steady. Look carefully at the water in the cylinder. Your eyes should be at the level of the top of the water. Notice that the top of the water is not flat. Record its shape.





3. Note the number touched by the lowest part of the top of the column of water. That is the volume of water in the graduate cylinder. Record it in Table F·1.

4. Empty half the water out of the cylinder. Record the volume of the water that is left. Add water until the graduate cylinder contains exactly 75 ml. Have your teacher check it.

5. Pour water into the 10-ml graduate cylinder until it is about two-thirds full. Record the volume of water in the cylinder. Pour out half the water in the cylinder. Record the volume of the water that is left.

Observing . . .

A. Number of small sections between each number on the side of your graduate cylinder: 10 How much volume does each of the small sections represent? 1 ml

B. Shape of the top of the column of water:

Curved upward at the edges.

C. Table F·1

Container	Volume of water (ml)
100-ml graduate (about 1/2 full)	Variable.
100-ml graduate (about 1/4 full)	
10-ml graduate (about 2/3 full)	
10-ml graduate (about 1/6 full)	

Name ____________________

Date __________ Class __________

ACTIVITY G: *Finding the density of a solid and of a liquid*

Materials: 1 Graduate cylinder, 0–100 ml
1 Meter stick
1 Equal-arm balance
1 Set of standard masses
1 Plastic block
1 Wood block
Water
Alcohol

Investigating . . .

Volume is the measure of the space taken up by a substance. *Density* is a measure of the amount of material in a given volume of a substance. That is, density is the ratio of the mass of a substance to its volume.

First find the density of a solid.

1. Measure the length, width, and height of each block. Record your measurements in Table G•1. Calculate the volume of each block in cubic centimeters (cc). It's easy to get the volume of a block. Just multiply length × width × height.

2. Then use the equal-arm balance to find the mass of each block. Record your results in Table G•1.

3. Density is measured in grams per cubic centimeter (gm/cc). To find the density of an object, divide its mass in gm by its volume in cc. Calculate the density of each block. Record the density in Table G•1.

Now find the density of a liquid.

1. Find and record the mass of your graduate cylinder.

2. Pour exactly 50 ml of water into the cylinder. One ml is the same as 1 cc. So the volume of the water is 50 cc.

3. Find and record the mass of the cylinder and water. Subtract the mass of the cylinder to find the mass of the water. Record your results in Table G•2.

4. Now calculate and record the density of the water.

Repeat steps 1 through 4 using 70 ml of water. Then find the density of alcohol. First use 50 ml of alcohol. Then use 70 ml of alcohol.

The mass and density of the alcohol in Activity F will depend upon the alcohol you use. You will have to use the weight and volume figures on the bottle to find the density.

Observing . . .

Volume of a solid (cc) = length (cm) × width (cm) × height (cm)

$$\text{Density (gm/cc)} = \frac{\text{mass (gm)}}{\text{volume (cc)}}$$

A. Table G•1

Substance	Length, cm	Width, cm	Height, cm	Volume, cc	Mass, gm	Density gm/cc
Plastic block						
Wood block						

B. Table G•2

Substance	Mass of empty cylinder, gm	Mass of full cylinder, gm	Mass of substance, gm	Volume of substance, cc	Density gm/cc
Water (50 cc)	Variable		50	50	1
Water (70 cc)			70	70	1
Alcohol (50 cc)	Variable		See	50	See
Alcohol (70 cc)			note	70	note

APPENDIX B: ADDITIONAL NOTES

LABORATORY TECHNIQUES

Disposal of chemical wastes:

Requirements for disposal of chemicals vary from place to place. We suggest that you call your local sanitary district for regulations in your area. We also suggest that you consult with the school custodian before emptying any chemicals down the drain.

Inserting glass tubing into rubber stoppers:

1. Lubricate the hole of the stopper and the surface of the tubing with liquid soap, glycerine, or Vaseline.
2. Hold the tubing close to the place where it is to enter the stopper.
3. Wrap a cloth around your hand or the tubing at the place where your hand and the tubing come in contact. This will prevent injury if the tubing breaks.
4. Push the tubing into the stopper by gently twisting the tubing back and forth.
5. Hold the tubing so it is not aimed at the palm of the hand holding the stopper. If the tubing should slide too easily through the stopper, you might push the glass into your hand.

PREPARATION OF CHEMICAL SOLUTIONS AND SAMPLES

Be sure that all chemicals and solutions are fresh; otherwise your results may be affected.

CHAPTER 16

Samples for Problem A: We have assumed there are 16 lab groups per class (2 students per group). The samples you put out should be *powders*, rather than crystals.

Place each sample on a separate sheet of paper. Do not put the names of the substances on the samples, only a number. Set out the following quantities and masses of each:

Sample	Quantity	Mass, gm	Substance
#1	9	10	Copper II nitrate
#2	9	10	Copper II carbonate
#3	9	10	Copper II sulfate
#4	9	10	Calcium carbonate
#5	9	10	Potassium chloride
#6	9	10	Sodium acetate
#7	10	10	Sodium tetraborate

Mixture sample for Problem B: For a class of 32, mix 80 gm of copper II carbonate and 80 gm of copper II sulfate. The mixture should be powdered, and the particles should look much alike. It need not look homogeneous.

Divide the mixture into 16 samples of 10 gm each. Place each sample on a separate piece of paper and put all samples on a table somewhere in the classroom.

If you wish to reduce the amount of chemicals used, have students reduce the amount of water mixed with the sample accordingly. For example, if a 5 gm sample is used, then use 50 ml of distilled water instead of 100 ml.

Copper II carbonate is insoluble in water.

CHAPTER 17

Solutions for Problem C. These are sufficient for 40 lab groups (2-4 students per group).

1. Potassium iodide solution, 1 molar. Dissolve 16.6 gm of potassium iodide in 500 ml of distilled water. Add 1 gm of $Na_2S_2O_3 \cdot 5H_2O$ (Hypo) and dilute to 1000 ml.

2. *Potassium persulfate #1.* Dissolve 13.5 gm ($K_2S_2O_8$) in 300 ml of distilled water. Dilute to 500 ml.

3. *Potassium persulfate #2.* Dissolve 13.5 gm ($K_2S_2O_8$) in 150 ml of distilled water. Dilute to 250 ml.

4. *Starch solution.* Heat about 60 ml of distilled water in a beaker. While the water is heating, put 1/2 teaspoon of starch in a test tube. Add 5 ml distilled water and shake the test tube. When the water in the beaker reaches a boil, add the starch-water mixture. Stir, boil for 1 minute, and set aside to cool. Pour the cooled starch solution into a dropper bottle labeled STARCH solution. The solution will remain usable for one week. Then a new solution must be prepared.

CHAPTER 18

Samples and solutions for Problem A: For a class with 16 lab groups, you will need 16 strips of each metal. These strips are found in scientific supply catalogs, listed as electrodes for electrochemical cells. Each lab group will need four strips of one kind of metal.

Prepare 2 liters of each solution as follows:

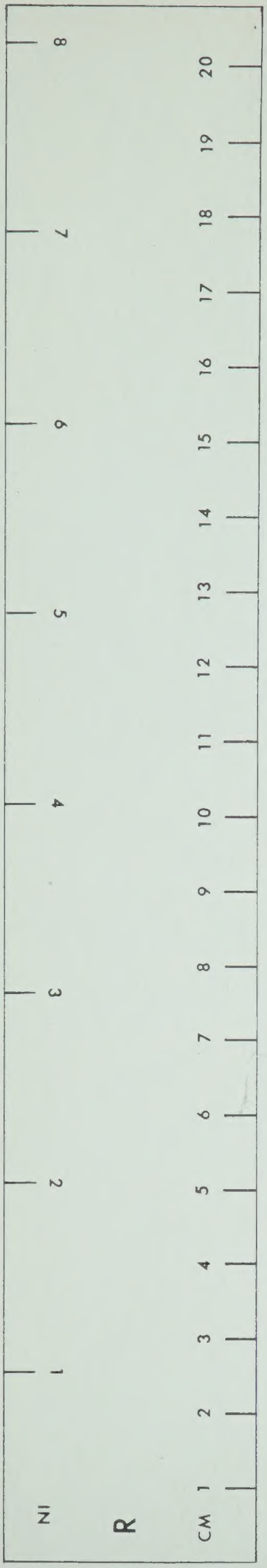
1. *Solution A—$FeSO_4$*. Dissolve 56 gm of $FeSO_4 \cdot 7\,H_2O$ in 1 liter of distilled water. Dilute to 2 liters. This solution must be made up fresh each day.
2. *Solution B—$ZnSO_4$*. Dissolve 36 gm of $ZnSO_4 \cdot H_2O$ in 1 liter of distilled water. Dilute to 2 liters.
3. *Solution C—$SnCl_2$*. Dissolve 44 gm of $SnCl_2 \cdot 2\,H_2O$ in 1 liter of distilled water. Dilute to 2 liters.
4. *Solution D—$CuSO_4$*. Dissolve 50 gm of $CuSO_4 \cdot 5\,H_2O$ (tech powder) in 1 liter of distilled water. Dilute to 2 liters.

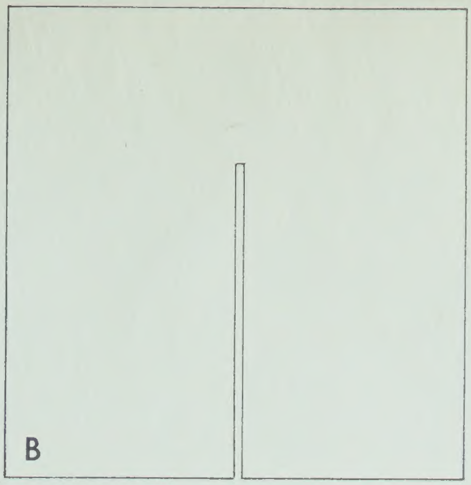
Divide each solution into 20 samples of 100 ml each. This will give you enough for 16-20 lab groups.

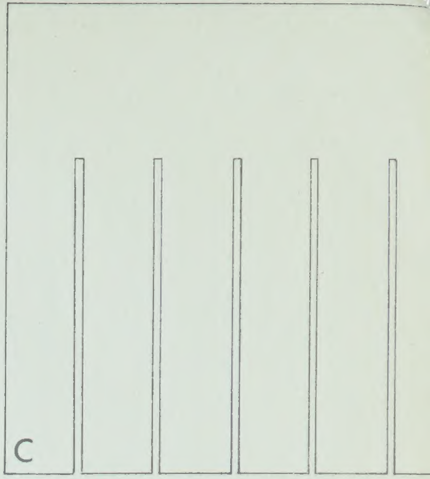
You can use the technical or pure form of any of the above salts. ACS Reagent grade chemicals are not necessary. The least costly salts of the required metals have been chosen.

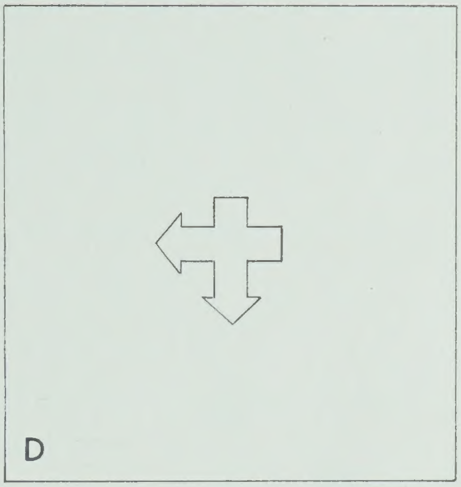
Silver and silver nitrate have been left out of this series because of their expense. You may wish to use them on a demonstration basis.

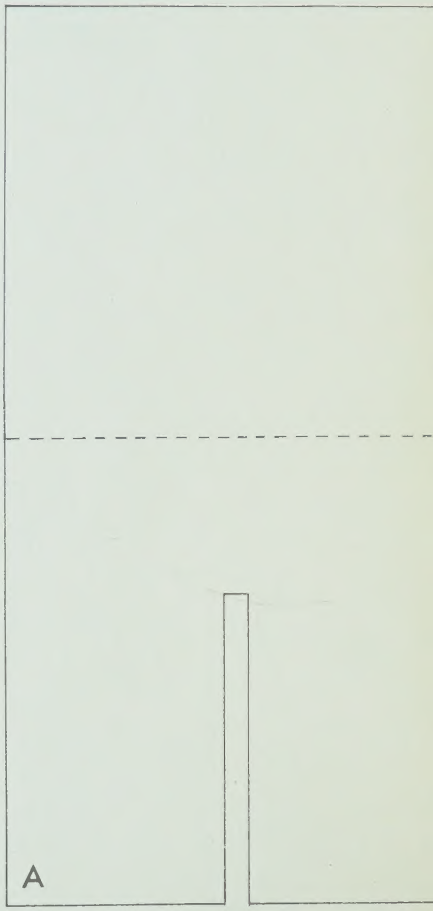
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 81 80 79 78 77 76 75
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 81 80 79 78 77 76 75

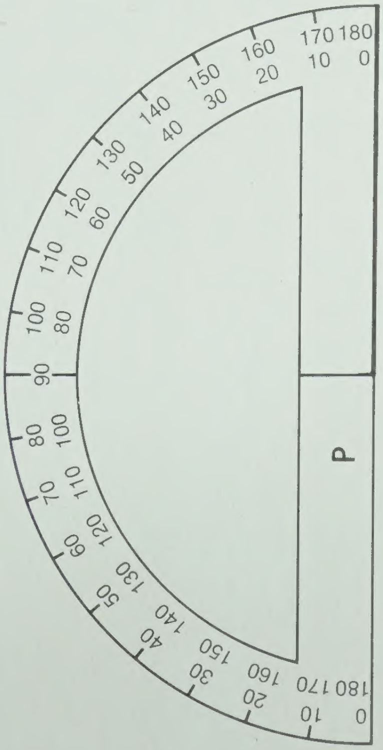




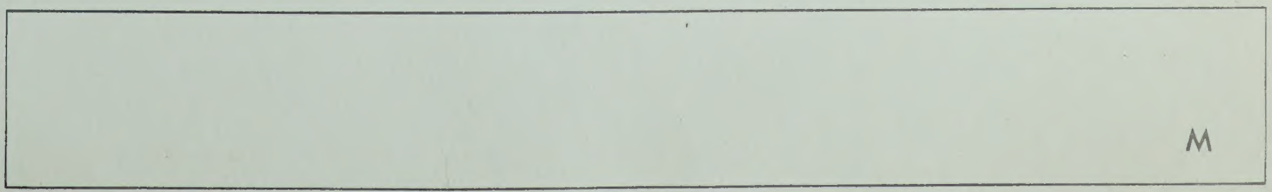








Cut the paper slide labeled *A* to fit the type of projector used in your classroom.



DATE DUE SLIP

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DUE EDUC. APR 12 '93
MAR 29 RETURN
EDUC DEC 03 1993
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TOWNSEND RONALD D
ENERGY MATTER AND CHANGE

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Q 163 T74 1973 Lab. Bk C. 3
Townsend, Ronald D.
Energy, matter, and change;

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